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A THERMOMETRIC TITRATOR

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ABSTRACT. — The construction of an inexpensive thermometric titrator is described whose linearity over a temperature range of 12° makes calibration easy.

The change in reaction temperature as a means of titrametric endpoint determination was first reported by Bell and Cowell in 1913. Further work on thermometric titrations followed using thermometers and ordinary burets (a review can be found in Linde, Rogers, and Hume, 1953). Because of thermometer response time lag, these titrations were long and tedious to perform making thermometric titrations unpopular. In 1953, a breakthrough occurred when Linde, Rogers, and Hume employed modern thermistor technology and continuous titrant addition to make thermometric titrations a fast, easy and now popular procedure. A unique and very useful feature is that the temperature change is not dependent upon free energy or equilibrium constants but on enthalpy (Jordan, 1958). For example, boric acid upon titration with sodium hydroxide gives as sharp a break at its equivalence point as hydrochloric acid.

In a thermistor bridge the thermistor is one arm of an equal-arm Wheatstone bridge with the unbalance voltage displayed on a recorder. Disadvantages of published thermistor bridges are nonlinearity over more than about 1°C and/or cost. A thermistor bridge based on a design by Averson (1967) is described here (see Figure 1) which is well suited for student use at a cost of less than $20 (since many of the components are on hand in

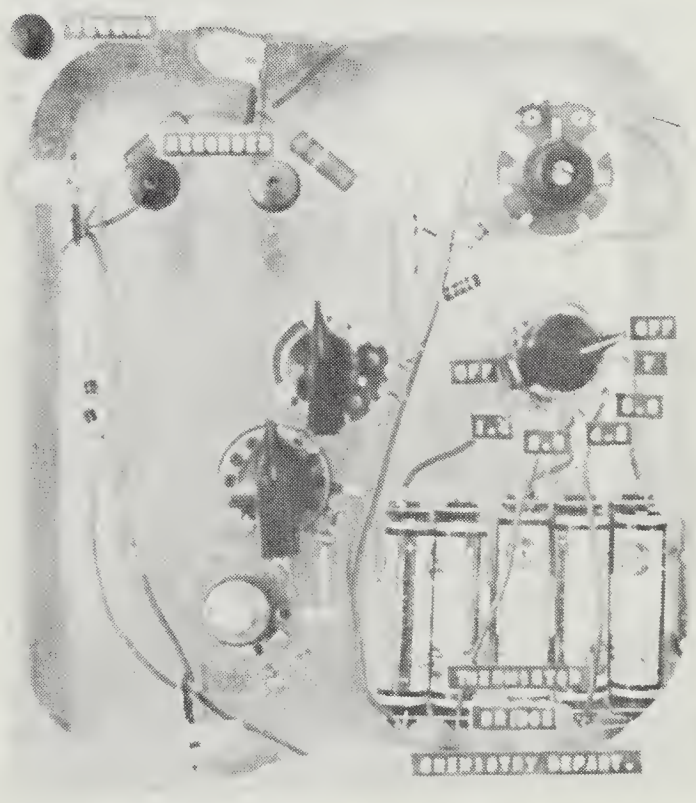

FIGURE 1. A student thermometric titrator.

most science departments, the actual cost is much less). Full scale readings on a 10 mv recorder vary from 1.4°C to at least 13°C and are linear with temperature as shown in Figure 2 thus making calibration easy.

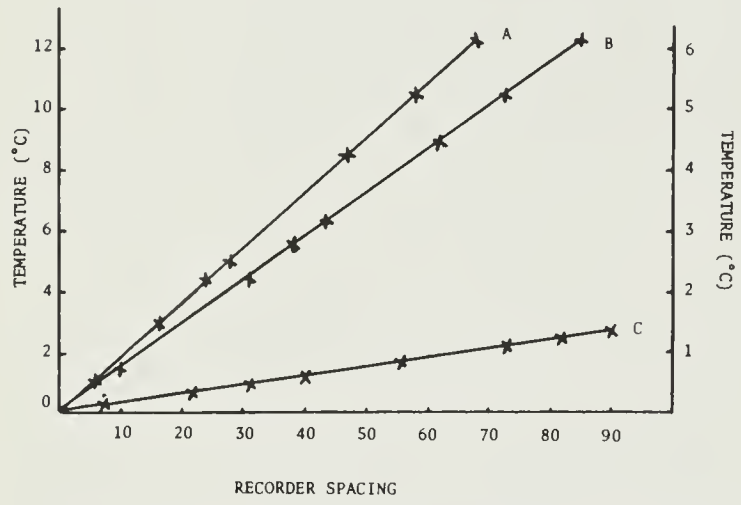

FIGURE 2. A, 12° range, 1.4 volts; B, 6° range, 1.4 volts; C, 1.4° range, 7 volts.

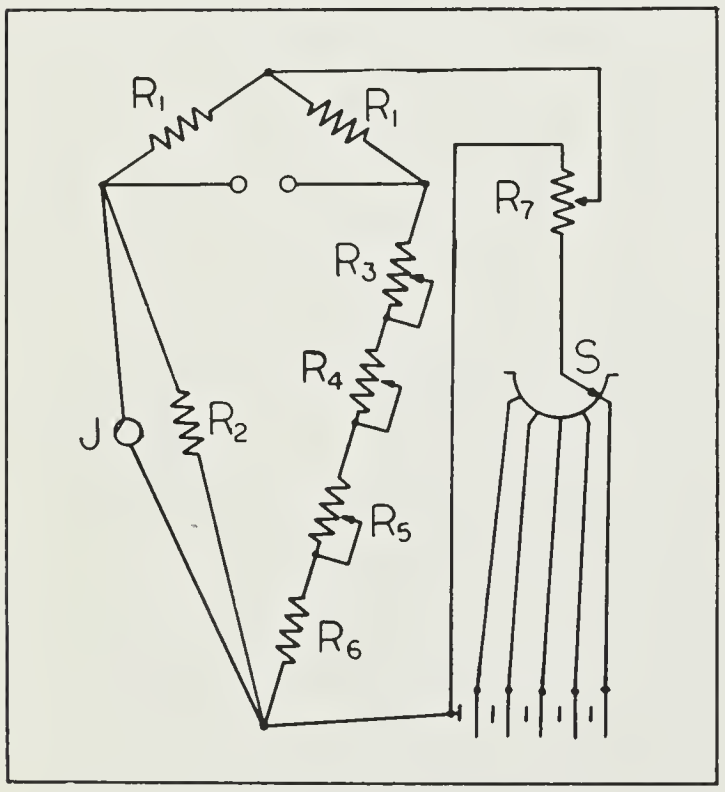

FIGURE 3. Circuit diagram of thermometric titrator.

The circuit is shown in Figure 3 as it is actually laid out with component values given in Table 1. Mercury cells of 1.4 volts, ½ watt 10% carbon resistors and ordinary variable resistors are used. The apparatus

TABLE 1. Components

R_1 82K	R_5 20 ohm
R_2 10K	R_6 4.7K
R_3 5K	R_7 25M
R_4 100 ohm	
S — Rotary switch, 12 positions	
J — Phone plug	

is housed in a 7-x 7½-x 2- inch aluminum box with its top cut out and replaced with ⅛ inch plexiglass so that students can see the various components. The two arms of the bridge and the voltage circuit are each of a different color wire for easy circuit tracing.

Thermistor resistance on the usual Wheatstone bridge is effectively linear over temperature ranges of about 1°C, but beyond that nonlinearity results. To extend the linear range, the current is made more constant by placing much larger resistances in the upper arms of the Wheatstone bridge than in the lower arms. Also, the thermistor is shunted by R_2.

A Fenwall 15K glass probe thermistor is cemented with epoxy into a glass tube, and the leads are lengthened to extend from the tubing and connected with alligator clips to a jack. A 10 mv recorder gives a full scale reading of 1.4°C using 7 volts across the bridge. Temperature span can be adjusted to any value greater than 1.4°C by varying R_7.

Several 10% carbon resistors are placed in series so that their resistances are equal to that of the thermistor at several temperatures around 25°C. The resistors are then calibrated in terms of temperature against a thermometer which reads to 0.02°C. These resistors are here-

after used for calibration instead of a thermometer.

To use the thermistor bridge, the bridge is balanced with the thermistor in place at the beginning of the temperature range to be used. The alligator clips are detached from the thermistor and attached first to one calibration resistor of known temperature equivalent and then another meanwhile changing the value of R_7 until a suitable temperature span is obtained. The clips are reattached to the thermistor and the bridge is set to work.

The titrant is delivered from a Mariotte bottle with a 220 mm piece of broken thermometer tubing used as capillary to give a constant delivery rate of $0.45^{\pm}$ 0.02 ml/min. The adiabatic titration cell consists of a drinking glass with a polystyrene insulator (as used for keeping drinks cold) inside a one liter beaker with vermiculite as additional insulating material. A cork stopper has three holes to admit the buret tip, thermistor and thermometer when used for calibration; all three are positioned just below the surface of the liquid. A magnetic stirrer operating about 360 r.p.m. is used to agitate the solution.

An example of the results which have been obtained is the titration of 100 ml of 0.050M hydrochloric acid with 1.00M sodium hydroxide. Five determinations gave a value of $0.0050^{\pm}$ 0.0003 mole of base.

The sensitivity of this bridge could be increased in several ways: a more sensitive recorder, a thermistor of higher resistance and a higher voltage across the bridge.

Acknowledgment

This work was submitted by Eldo Roy in partial fulfillment for the degree of Master of Science Teaching at Illinois Wesleyan University sponsored by the National Science Foundation. We are grateful to Herman L. Detweiler for several suggestions.

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A CYPRESS SWAMP OUTLIER IN SOUTHERN ILLINOIS

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ABSTRACT. — Two areas of cypress swamp in Johnson County, southern Illinois, were sampled; one was old-growth and the other a cut-over stand. A comparison is made of the two areas from the standpoints of basal area and density of the tree species. Structural diagrams are presented for both areas. The cut-over and old-growth stands both support high basal areas, 241.8 and 273.0 sq. ft. per acre respectively. A cypress dominance factor is presented that is linearly related to the number of cypress "knees" per acre. The five most frequent species of vascular plants on both the fallen logs and lower tree bases are *Bidens discoidea, Triadenum walteri, Lycopus rubellus, Boehmaria cylindrica,* and *Galium obtusum.* The logs had a total of 22 species, whereas the tree bases had only 16 species.

In the "First Report On A Forestry Survey," 1923, R. B. Miller indicated that cypress (*Taxodium distichum*) was a tree of considerable importance in Illinois. It was then and is now limited to the southern portion of the state, occurring in the river bottoms of the Mississippi near McClure, the Cache River, and the backwaters of the Ohio, being most abundant in Alexander, Pulaski, Massac, Union, and Johnson counties.

The original acreage of pure and mixed cypress forests in Illinois probably did not exceed 250,000 acres; the best forests were formerly found in the Cache River bottoms (Telford, 1926). As a result of logging and subsequent drainage of these swamps for agriculture this community has been reduced to a few small scattered remnants.

This paper presents the ecology of Heron Pond, one of the last remaining old-growth cypress swamps. Heron Pond was so named because a large number of great blue herons nest there. American egrets also use the rookery at the western end of the pond. The pond is approximately in the center of section 30 of T 13 S, R 3 E, about 5 miles south of Vienna, the county seat of Johnson County. The pond, about 90 acres in size, receives flood water from the Cache River. The soil of Heron Pond is mapped as a Piopolis Clay, a poorly drained, acid, fine-textured soil, a silty clay loam (Fehrenbacher and Walker, 1964).

The average January temperature at New Burnside, 20 miles to the northeast, is 34.6°F., and the average July temperature is 78.6° F. The average rainfall is 45.1 in. and the length of the growing season is about 187 days (Fehrenbacher and Walker, 1964).

At the time of sampling, in late August and September of 1968, the water depth in the pond varied from 2 to 4 ft., and local residents indicate that the pond never dries up. The water has risen in recent years due to beavers constructing a dam across the pond outlet that drains into the Cache River. Several acres

of hardwoods have died as a result of this flooding. In some areas the beavers have removed large numbers of water tupelo (*Nyssa aquatica*). However, *Nyssa* is the only species greatly affected by the beavers.

Hardwoods along the north edge of the pond were cut to salvage them before permanent flood damage occurred. Various areas of the swamp have been lumbered at different times during the past 75 years.

Methods

Within Heron Pond two areas with different histories were sampled. One was cut-over and the other was an old-growth stand, apparently never logged. The old-growth area was characterized by having a more continuous canopy, fewer fallen logs, and an absence of stumps. The cut-over stand had a more broken canopy, numerous stumps, a greater density of shrubs, and many fallen logs.

Six one-fifth acre circular quadrats were used to sample trees; no trees less than 3.5 in. (dbh) other than seedlings were encountered. Three quadrats were located randomly in the second-growth area; however, the uncut section was about an acre in size and irregular in shape, so that random placing of the plots was not possible. Here the three quadrats were located so that they did not overlap or extend into the cut-over area.

The herbaceous vegetation and small shrubs on fallen logs and lower tree trunks were sampled in 10 cm x 10 cm quadrats. The sampling plot was divided into four quadrants, and the herbaceous vegetation and shrubs on the two closest trees in each sector were sampled. Only trees large enough to place four 100 cm^2 quadrats on their base without overlap were used. The quadrats were located on the trunks between the cardinal directions, at approximately the high water line, where the largest mass of plants occurred. On the fallen logs the quadrats were located at meter intervals the entire length of the log.

The taxonomic nomenclature follows that of Gleason, 1963.

Results

All tree stems were measured at 4½ feet above the ground. The resulting basal areas are high and not comparable to other communities because of the buttressing of cypress. Other workers have measured above tree buttresses to make the basal areas comparable to other communities (Telford, 1926; Davis and Richards, 1934).

Figure 1 shows the relationship between diameters at 4½ ft. and 7 ft. for 33 cypress trees measured in the study area. The relationship between the two variables is linear

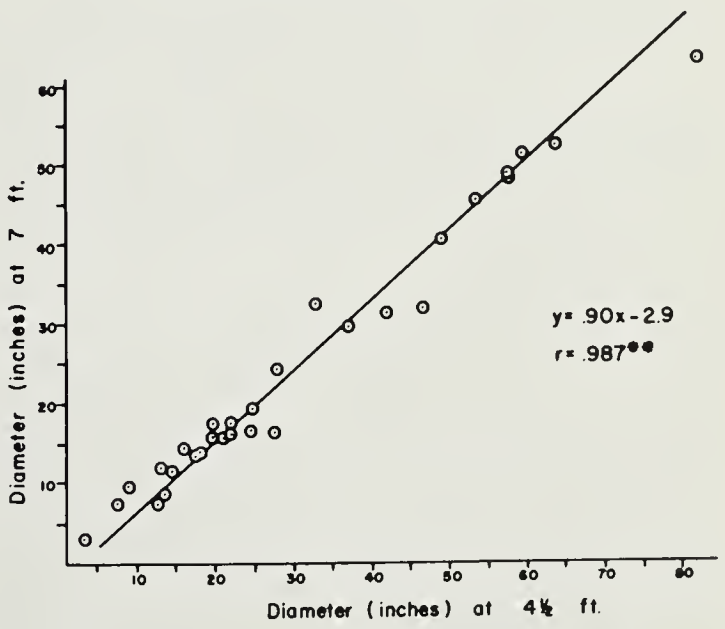


Figure 1. The relationship between 4½ ft. and 7 ft. diameters of cypress.

across a range of diameters from 3 to 83 in.; the correlation coefficient, .987, is highly significant. The basal areas at these two heights would not be related linearly, basal area being a function of the square of the radius. The diameter measurements taken at 4½ ft. in the quadrats were converted to 7 ft. diameters using the regression equation given in Figure 1.

In Table 1 the basal area per acre for both stands are given for all species at 4½ ft. and for cypress at 4½ and 7 ft. Stems per acre greater than 3.5 in. dbh is given, as well as an Importance Value based on relative density and relative dominance. The Importance Value has been scaled so that the sum of all I.V.'s equals 100. The basal areas determined for cypress at 7 ft. were used in the calculation of relative dominance and the calculation of total basal areas for both stands.

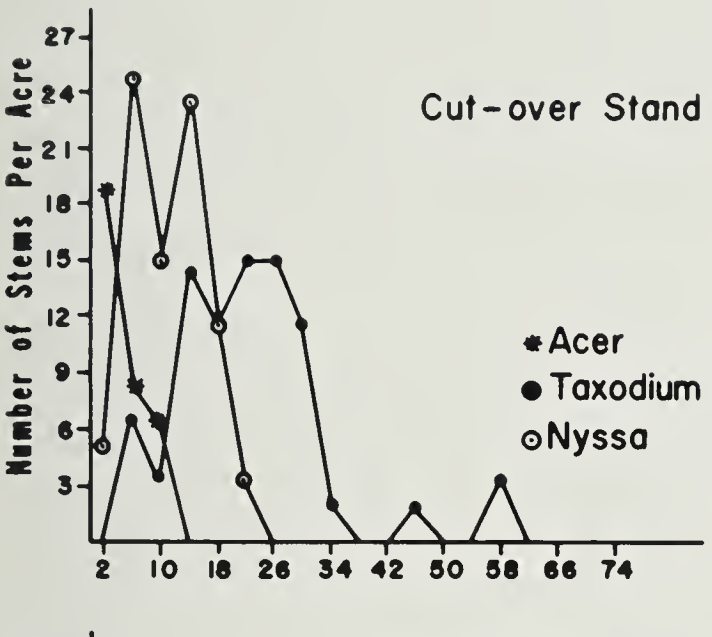
Both areas studied support high total basal areas per acre. The old-growth stand has the highest with 273.0 sq. ft., compared to 241.8 for the cut-over area. These basal area measurements are higher than most Illinois communities; however, Schmelz and Lindsey (1965) reported 199 and 152 sq. ft. for portions of Beall Woods, south of Mount Carmel, Illinois, and the basal areas are not excessively high when compared with other cypress communities. For example, Wagner and Kurz (1962) found 300 sq. ft. per acre for a cypress stand in Louisiana. Similarly, Schmelz and Lindsey (1965) reported 228 sq. ft. for a cypress swamp in Indiana.

Cypress dominates both stands but is more important in the old-growth stand. Its Importance Value in the cut-over stand is 58.1 compared to 82.4 in the old-growth stand. The Importance Values of tupelo and Drummond's maple are respectively 36.3 and 5.6 in the cut-over area compared to 14.7 and 2.9 in the old-growth stand. Cypress

TABLE 1. A summary of some quantitative ecological measurements for the two study areas.

	Cypress	Tupelo	Maple	Totals
Cut-over stand				
Density/Acre	83.3	81.7	16.7	181.7
BA/Acre				
at 4½ ft.	271.3	66.6	4.8	342.7
at 7 ft.	170.3			241.8
Rel. Density	45.9	44.9	9.2	100.0
Rel. Dominance	70.4	27.6	2.0	100.0
(I.V. on the basis of 100)	58.1	36.3	5.6	100.0
Old-growth stand				
Density/Acre	93.3	31.7	6.7	131.7
BA/Acre				
at 4½ ft.	375.4	14.4	1.9	391.7
at 7 ft.	256.7			273.0
Rel. Density	70.9	24.0	5.1	100.0
Rel. Dominance	94.0	5.3	.7	100.0
(I. V. on the basis of 100)	82.4	14.7	2.9	100.0

not only has more basal area in the old-growth stand but a higher density as well.



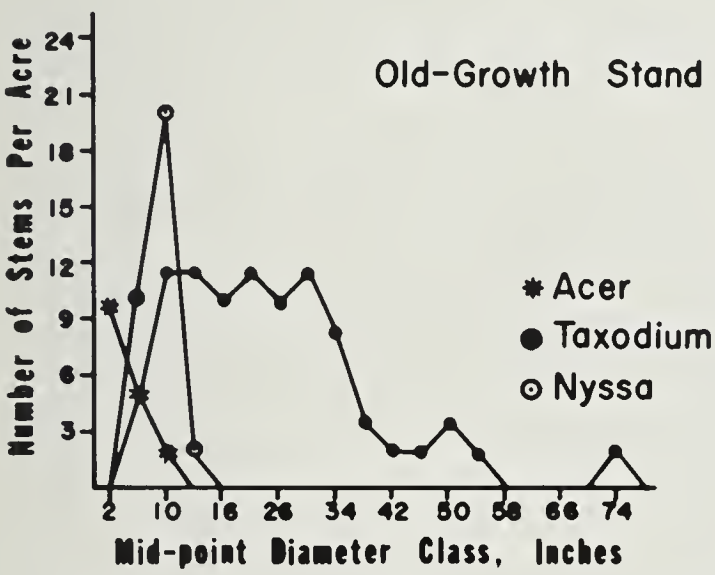


FIGURE 2. Structural diagrams for the old-growth and cut-over stands.

The structural diagram, Figure 2, shows that both cypress and water tupelo are even-aged populations. The few very large individuals in the cut-over area are hollow and were apparently by-passed by the loggers. This area has more tupelo and maple in the smaller size classes than does the old-growth stand. Only the maple has the "J shaped" curve characteristic of all-age populations.

In Figure 3 the relationship between the number of "knees" per acre and the cypress dominance factor is shown. The "knees" were tallied in each of the six quadrats. Connected knees were counted individually if they were separated above the water level. The cypress dominance factor is the square root of the product of the average tree basal area (dbh) and the density of cypress trees per acre. The square root of the product was used to achieve linearity for regression purposes. The correlation coefficient, .91, is significant at the .05 level.

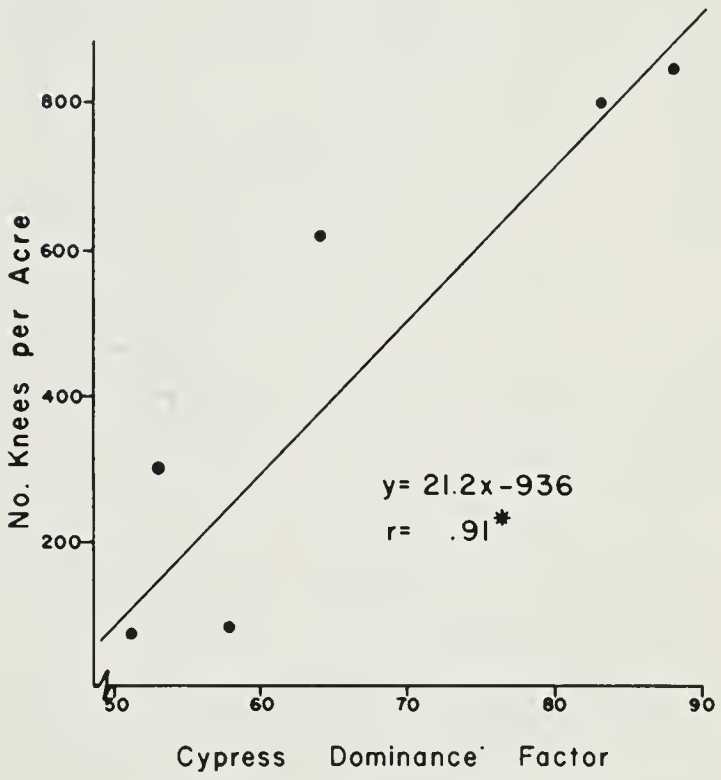


FIGURE 3. The relationship between the cypress dominance factor and the number of knees per acre.

Because the number of "knees" increases as the number and size of the cypress trees become greater, the two variables, average tree basal area and density, could be expected to be related to the density of "knees." Combining these two variables into a single expression yields

a term that has a better predictive value than either of the two variables independently. The relationship between the number of "knees" and the average basal area and density might be expected to exist for cypress in a wide range of habitats. However, the regression equation given in this paper probably will not be functional in other habitats. The number of "knees" is also a function of the habitat, and habitat differences are not considered in the equation.

The quadrat frequencies for the herbaceous vegetation and shrubs on the tree bases and on the fallen logs is given in Table 2. Mosses of various species have the highest frequencies on the tree trunks and on the fallen logs. *Bidens discoidea, Triadenum walteri, Lycopus rubellus, Boehmaria cylindrica,* and *Galium obtusum* are the five most frequent species of vascular plants on both the fallen logs and the tree bases. However, the fallen logs have a somewhat richer flora with 22 species being present compared with 16 for the tree bases.

Dodder (*Cuscuta cuspidata*) was found only on logs and was usually parasitizing *Triadenum walteri.*

Chi square tests were used to determine species preferences for N.E., S.E., S.W., or N.W. sides of the trees. However, none were found to be significantly associated with any

TABLE 2. Quadrat frequencies and species list for plants growing on tree bases and fallen logs.

Species	Frequency (172 Quadrats) on buttresses (16 species)	Frequency (60 Quadrats) on fallen logs (22 species)
Moss spp.	94.2	98.3
Bidens discoidea	55.2	41.7
Triadenum walteri	31.4	58.3
Lycopus rubellus	27.9	43.3
Boehmeria cylindrica	14.5	41.7
Galium obtusum	12.2	48.3
Rosa palustris	5.2	13.3
Scutellaria lateriflora	4.1	Present only*
Itea virginica	4.1	21.7
Cuscuta cuspidata		11.7
Cyperus sp.		5.0
Rhus radicans	Present only	3.3
Impatiens biflora	" "	1.7
Carex sp.		1.7
Parthenocissus quinquefolia	Present only	
Smilax sp.	" "	
Rubus sp.		Present only
Vitis sp.		" "
Lobelia cardinalis		" "
Cyperus esculentus		" "
Cyperus erythrorhizos		" "
Seedlings:		
Ulmus sp.	Present only	Present only
Acer rubrum var. Drummundii	" "	" "
Taxodium distichum	" "	" "

* These plants grow on the logs or buttresses, but never occurred in a quadrat.

aspect of the tree. For the five most frequent species, occurring on the tree bases, chi square tests were used to examine the preference of these species for substrate. Only *Triadenum walteri* showed a significant positive preference (.001 level), occurring more frequently on cypress than on Drummond's red maple or water tupelo.

Azolla mexicana and *Spirodela polyrhiza,* floating aquatics, formed a dense cover over the surface of the water during August and September of 1968. On September 28, 1968, a circular can with the bottom removed was used to harvest *Ceratophyllum demersum,* a submerged aquatic, in five locations. The total area harvested was 363 sq. in. The average dry weight of *Ceratophyllum* was 44.16 grams per sq. meter.

Three shrubs were prominent in the cypress swamp, the button bush (*Cephalanthus occidentalis*), Virginia-willow (*Itea virginica*), and the swamp rose (*Rosa palustris*). The button bush formed a dense cover in some areas, but was never found on tree bases or on fallen logs, whereas the Virginia-willow occurred on logs, tree bases and in the water.

Reproduction by the trees was slight and limited to the fallen logs and swollen bases of tupelo and cypress. No tupelo seedlings were encountered, but a few *Taxodium* seedlings were found on fallen logs and tree buttresses. Drummond's red maple never grew directly in the water and was always restricted to fallen logs or old stumps. Even the largest maple trees did not grow directly in the water. It is questionable whether the cypress seedlings found on stumps, logs and swollen trunks are able to attain canopy positions; red maples are able to reach tree size starting from these substrates.

Discussion

The occurrence of trees, floating and submerged aquatics, epiphytes on the tree bases, and floating logs resembling vegetated islands makes the cypress swamps an interesting habitat ecologically.

Structurally the forest of Heron Pond is simple with the two dominant tree species being even-aged populations. Neither cypress nor water tupelo are able to germinate directly in the water so that large numbers of seedlings can get started only when the water recedes. Similarly, the seedlings are unable to withstand complete submergence (Demaree, 1932).

The structural diagrams suggest that the cypress populations in both areas might have originated about the same time. However, the cut-over area had some of the larger individuals selectively cut, suggested by the pattern of stumps. This disturbance may have permitted the tupelo present in the stand to be released, accounting for larger numbers and greater size of tupelo. Fallen logs and stumps would have provided suitable substrates for Drummond's maple to become established.

The importance of maple in a cypress swamp might be expected to increase after a disturbance such as cutting or as the canopy begins to break up, so that there are more fallen logs and stumps available for seed germination and lessened com-

petition for light and space.

The largest tree sampled was 74 in. (dbh); the largest cypress tree in Heron Pond measures 83 in. (dbh). Voigt and Mohlenbrock (1964) quote Brendel (1881) who indicates that the largest tree he ever measured in Illinois was a bald cypress 2.1 meters in diameter (82.6 in.), indicating that some trees in Heron Pond are as large as those in the primeval forest of Illinois.

Taxodium is an initial tree in deep swamps that occasionally have low water levels. According to Matton (1915) trees in virgin cypress stands were commonly 400 to 600 years old. He also states that old-growth stands of cypress have slow growth rates, while younger stands grow at rates comparable to other bottomland hardwoods with trees reaching diameters of 21 in. in one hundred years. This suggests that numerous trees in Heron Pond are older than a century, and that if undisturbed *Taxodium* will retain dominance for several centuries. But, with cutting of the cypress, water tupelo and red maple will increase in importance.

Kurz and Demaree (1934) indicate that the best development of "knees" and buttresses occur where air and water act together on wood-forming tissues. However, work done in Indiana has shown that "knees" develop on cypress trees grown on a wide range of sites, some of which experience little or no inundation. "Knees" were considered to be an inherent characteristic of the species (DenUyl, 1962).

The cypress dominance factor was found to be linearly related to the number of "knees" per acre, with the number of "knees" increasing as the number of cypress trees increase or as they get larger. However, the relationship would have to be determined for each habitat, as the number of "knees" is related to the site conditions.

Koelling (1968) indicates that *Bidens discoidea* and *Lycopus rubellus* are common herbaceous plants on buttressed tree bases in southern Illinois swamps. In this study they were the first and third most frequent species of vascular plants on the buttresses. Fallen logs have a richer flora than the buttresses perhaps because they offer a somewhat more favorable environment, due to the rich moss growth and the moist decaying wood that are favorable for the germination and growth of herbaceous plants.

Acknowledgment

The authors would like to acknowledge Jacob Verduin of the Department of Botany at Southern Illinois University for his critical review of the manuscript.

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CEPHALASPIDS FROM THE MIDDLE ORDOVICIAN PLATTEVILLE LIMESTONE

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ABSTRACT. — The remains of exoskeleton parts of Ostracoderms, cephalaspids, were collected from the Platteville Limestone (Middle Ordovician-Black Riveran) in two quarries near Dixon, Lee County, Illinois. The two best specimens, which are figured and described, consist of one medium-sized individual with most of the head shield, a pectoral fin and part of the trunk preserved, and one large, disarticulated pectoral fin. The specimens appear to belong to species of the Order Osteostraci, Family Hemicyclaspididae (Ateleaspidae). The remains are dolomitized and, hence, do not retain the structures of bone as viewed in thin section.

To my knowledge no Ordovician fish remains have been reported from the Midwest. Denison (1967) reviewed old material and described and figured new material from the Middle Ordovician Harding Sandstone (Black Riveran) of the West. The material reported here was largely collected from a quarry southwest of Dixon (SE¼ NE¼ Sec. 12, T.21 N., R.8 E.), Lee County, Illinois. A few specimens were found as float in the Medusa Cement Company quarry just northeast of Dixon (Figure 1). All of the material is dolomitized.

The cephalaspid remains occur on erosional surfaces associated with argillaceous partings and along bedding planes in the yellowish-brown dolomite. Specimens also occur in the upper part of the underlying argillaceous blue limestones, again along erosional surfaces. The remains are fragmentary and/or crushed with some of the elongate parts, such as the pectoral fins,

FIGURE 1. North side of quarry southwest of Dixon. Arrows indicate beds containing cephalaspid remains.

showing alignment due to transport. Most of the remains, however, appear to be randomly distributed. Found associated with the cephalaspid remains are such marine invertebrates as brachiopods of the genus *Opikina*.

The first specimens were collected by John Washburn of the Illinois State Highway Department, Elgin. Additional material was collected by James C. Grenda, a graduate student in Geology at Southern Illinois University, Neil Healy of Sterling, Illinois and the author.

Our specimens were placed in the Order Osteostraci because of the closely-spaced eyes high on the head in the medium-sized specimen and in the Family Hemicyclaspididae because all of the pectoral fins preserved have thickened marginal rims. No cornua are developed.

The medium-sized individual (Figure 2) possesses a head shield which is wider than high, about 52 mm. X 33.5 mm. in maximum measurements. It has a raised, smooth, marginal rim anteriorly and laterally, about 2.5 mm. in width. The dorsal surface of the shield is finely tuberculate, but poor preservation does not allow recognition of any pattern, if one existed. The orbits are nearly round in outline, somewhat elongate, and about 3.5 mm. in diameter. The nasal fossa is also nearly round, but somewhat elongate, in outline, and is interrupted by a prominent medial ridge, anteriorly and posteriorly, which apparently bears the aperture, although the latter is not visible. The pineal plate is incompletely developed. The relatively large oval dorsal field is bounded laterally by two low ridges which join posteriorly with a low, dorsal crista. The latter continues posteriorly across the dorsal shield and on to the trunk. The lateral fields are large and roughly crescent-shaped. The posterior part of the dorsal shield is either segmented or bears several rows, two to three, of alligned plates. The trunk segments are wide and bear scattered, large tubercles on the surface. The portion of the trunk preserved is about 60 mm. long and relatively narrow. A large, about 16.5 mm. wide X 56 mm. long, pectoral fin is attached to the posterior side of the head shield. This pectoral fin is elongate, bent slightly trunkward and tapers posteriorly to a narrow, rounded end. The fin is ornamented with narrow, prominent, sinuous, radial ridges and coarse, marginal scales, which give the edges a knurled appearance. These sinuous ridges are also intermittently developed on the ventral fin surface. The upper fin surface is slightly convex upward. The posterior median margin of the head shield has a rounded, posteriorly-directed lobe. No evidence of the sensory canals is preserved.

The specimen described was apparently triangular in cross-section with an arched head shield.

The well-preserved, disarticulated pectoral fin (Figure 3) is tongue-shaped and measures about 152 mm. long X 40 mm. wide, medially. Prominent side scales give the fin edges a knurled appearance; while prominent, sinuous, narrow ridges ornament the dorsal and ventral fin surfaces, the latter of which is nearly flat and the former slightly convex upward. Median areas of the

Figure 2. Photograph of the described medium-sized specimen collected from yellowish-brown dolomite. Southern Illinois University Museum No. V-5.

dorsal fin surface bear prominent, narrow longitudinal ridges which cross the prominent, narrow, sinuous radial ridges, giving the surface a reticulate appearance. This pectoral fin is about 3 mm. thick, medi-

FIGURE 3. Photograph of the described well-preserved pectoral fin collected from yellowish-brown dolomite. Southern Illinois University Museum No. V-6.

ally. Wide segmentation is visible on the ventral side.

CONCLUSIONS

The range of the Osteostraci, cephalaspids, is extended back to Middle Ordovician, Black Riveran, times.

The Heterostraci were not necessarily older than the Osteostraci.

The older Silurian genera of Ostracoderms which lacked pectoral fins and possessed a head shield which covered a large portion of the trunk were not necessarily primitive forms.

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A FLORA OF PINEY CREEK RAVINE

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ABSTRACT. — A brief descriptive account of the geology, topography, and plant communities of Piney Creek Ravine, Randolph County, Illinois is presented, followed by a checklist of the 441 taxa thus far found in the area. An attempt is made to explain the unusual occurrence of some of the species in this unique floristic area.

A small, scenic area, unique both in its topography and vegetation, lies near West Point, Randolph County, in southwestern Illinois. This area had been relatively unexplored, until 1957, except for a few sporadic visits made by botanists collecting in southern Illinois. However, from these few investigations came reports of several rare specimens, which stimulated the author to undertake a more intensified study.

The site of these investigations is Piney Creek Ravine. It lies in the southeastern portion of Randolph County, except for the creek source, which originates in the northwest corner of Jackson County. The entire area (Figs. 1 & 2) consists of approximately 900 acres.

The first record of investigation in this area by any botanist was that of Miller and Tehon (1929) who made reference to a small stand of *Pinus echinata* Mill., one of two stands in the state, located in "a sandstone ravine of Piney Creek, near the town of West Point in Randolph County." A second record of collection in this area occurred nearly twenty years later in 1948, when G. N. Jones and G. D. Fuller (1955) listed West Point as the location for the same species of pine. More recently, in 1954, R. H. Mohlenbrock recorded from Piney Creek *Asplenium bradleyi* D. C. Eaton and *Ranunculus harveyi* (Gray) Britt., both new records for Illinois.

The drainage system is simple, consisting of Piney Creek and its several small tributaries, flowing chiefly from east to west directly into the larger Mill Creek. This latter stream, similar in its topography to Piney Creek, flows in a northwesterly direction until it reaches Mary's River. Finally, several miles to the west, this latter stream empties into the Mississippi River.

Through the process of erosion Piney Creek has gradually worn through sandstone forming a rocky ravine with high bluffs and steep slopes. This sandstone was formed during the Pennsylvanian Epoch and, for the most part, consists of rocks from the Caseyville Formation. However, a small portion of the area, in the vicinity of West Point, is made up of rocks from the Tradewater Formation, which

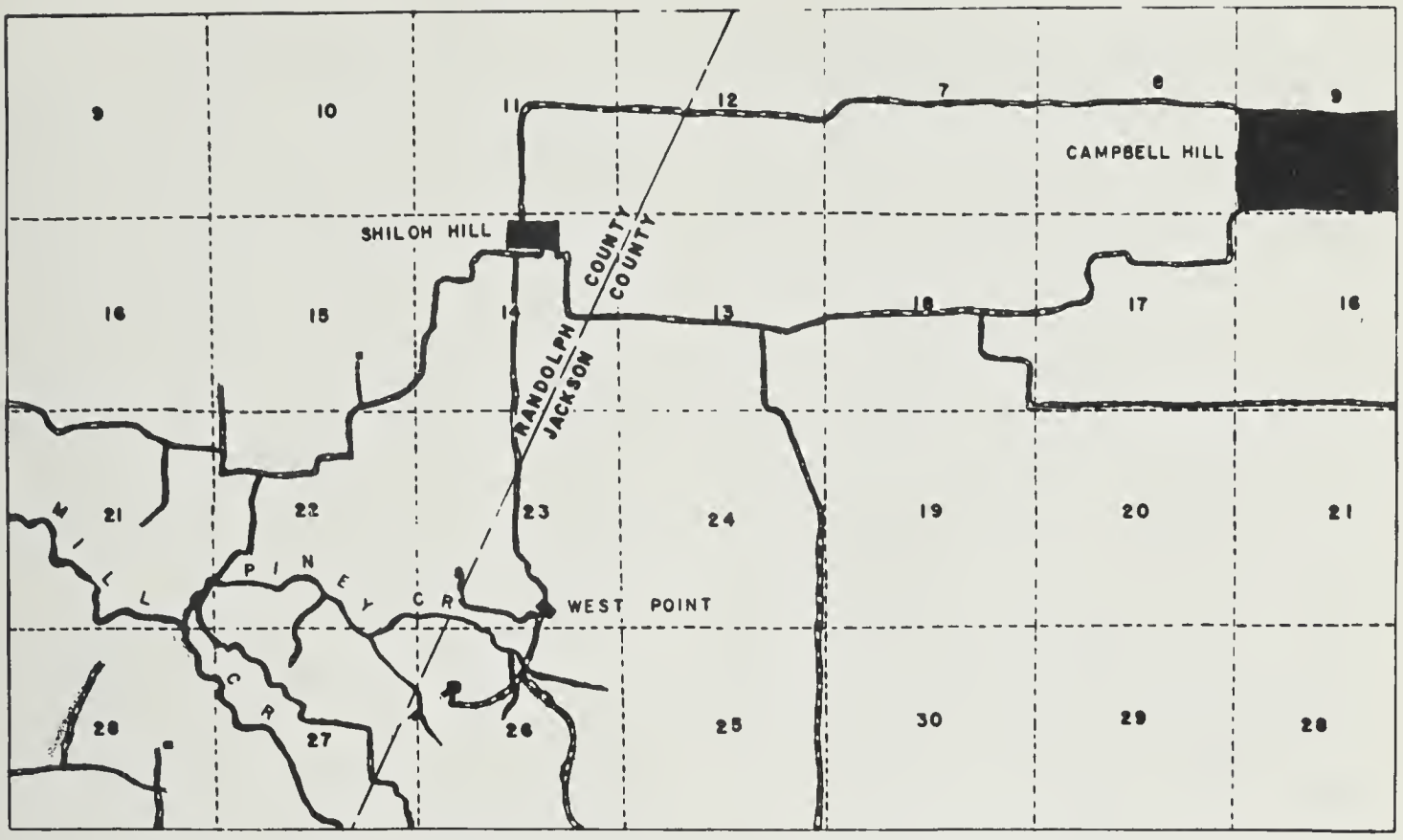

FIGURE 1. A Portion of the Campbell Hill Quadrangle Within R 5 W; T 7 S.

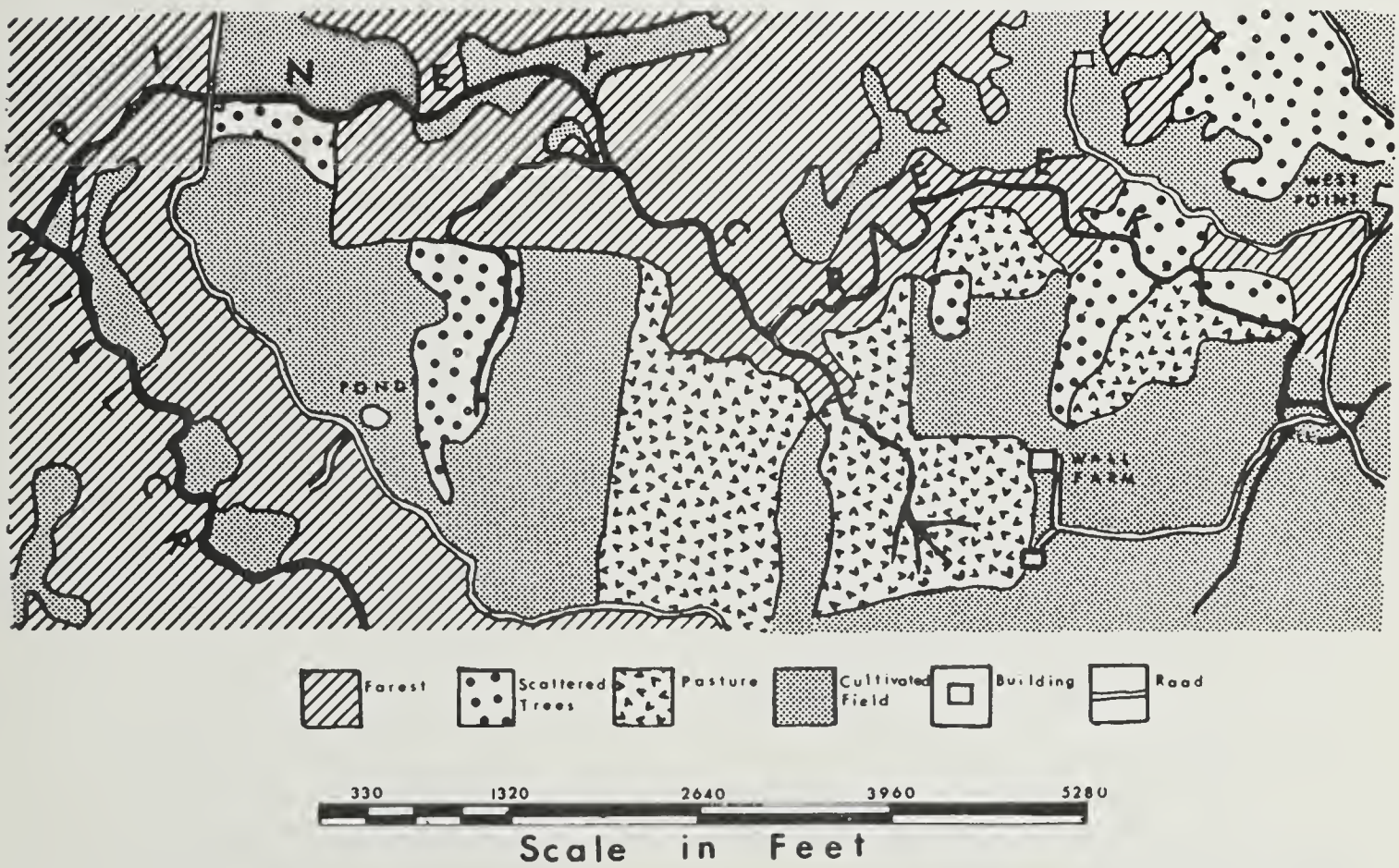

FIGURE 2. Map of Study Area Within Portions of Sections 21, 22, 23, 26, 27, and 28 Illustrated in Figure 1.

are considered by geologists to be the oldest of the epoch (Worthen, 1882).

Beginning at the source of Piney Creek, and continuing for approximately one-third of its course, a rather unique condition exists. Here the creek bed consists almost entirely of solid sandstone with occasional drops of one to ten feet, at the bottom of which are shallow or deep pools of clear water. Throughout this rocky area numerous "potholes" occur, as well as many long, narrow grooves, probably indicating weak areas of a less resistant sandstone.

The high bluffs and rocky walls consist almost entirely of massive cliff-forming beds of this sandstone, except for occasional thin-bedded strata in the lower sections. Along the sides of these high vertical walls are many moist, soil-covered ledges on which are found a large number of mosses and liverworts, plus a number of ferns and flowering plants. Covering slopes and bluff tops on both sides of the creek are narrow zones of forest, limited on the periphery by cultivated fields and pastures.

This entire area lies within the boundary of Pleistocene glaciation, which attained its most southern extension several miles south of Piney Creek with the advance of the Illinoian glacier. Following glaciation and subsequent wind activity, large amounts of loess were deposited; it is this type of soil that covers the bluffs along this stream. The soil of the alluvial valley, however, is of a very sandy texture and has resulted from the erosion of the exposed sandstone surfaces.

Results

After forty-four weeks of collecting in the vicinity of Piney Creek Ravine, the author identified the following taxa. The nomenclature followed in this list is that used in "New Britton and Brown Illustrated Flora of the Northeastern United States and Canada" (Gleason, 1952). Specimens have been deposited in the Southern Illinois University Herbarium.

An asterisk (*) preceding the taxon indicates a Randolph County new record. This information is based on species distribution maps in "Vascular Plants of Illinois" (Jones and Fuller, 1955), and at the time of collection represented county records.

Division Bryophyta
- Class Musci
  - Sphagnaceae
    - *Sphagnum capillaceum* (Weiss) Shank
- Class Hepaticae
  - *Cephaloziella subdentata* Warnstf. or *C. elachistata* (Jack) Schiffn.

Division Tracheophyta
- Subdivision Sphenopsida
  - Equisetaceae
    - *Equisetum hyemale* L.
- Subdivision Pteropsida
  - Class Filicineae
    - Ophioglossaceae
      - **Botrychium virginianum* (L.) Sw.
    - Polypodiaceae
      - *Adiantum pedatum* L.
      - *Cheilanthes lanosa* (Michx.) D. C. Eaton
      - *Polypodium vulgare* L. var. *virginianum* (L.) D. C. Eaton
      - *Asplenium trichomanes* L.
      - *Asplenium platyneuron* (L.) Oakes
      - *Asplenium bradleyi* D. C. Eaton
      - *Woodsia obtusa* (Spreng.) Torr.
      - *Cystopteris fragilis* (L.) Bernh.

Thelypteris hexagonoptera (Michx.) Weaherby
Dryopteris marginalis (L.) A. Gray
Polystichum acrostichoides (Michx.) Schott

CLASS GYMNOSPERMAE

PINACEAE

Pinus echinata Mill.

CUPRESSACEAE

Juniperus virginiana L. var. *crebra* Fern.

CLASS ANGIOSPERMAE

GRAMINEAE

**Arundinaria gigantea* (Walt.) Chapm.
**Bromus ciliatus* L. var. *intonsus* Fern.
Bromus commutatus L.
**Bromus racemosus* L.
Festuca elatior L. var. *arundinacea* (Schreb.) Wimmer
Festuca octoflora Walt. var. *tenella* (Willd.) Fern.
**Festuca octoflora* Walt. var. *aristulata* Dewey
Glyceria striata (Lam.) Hitchc. var. *striata* (Scribn.) Fern.
Poa compressa L.
**Poa chapmaniana* Scribn.
**Poa paludigena* Fern. and Wieg.
**Poa sylvestris* Gray
Eragrostis cilianensis (All.) Link
**Eragrostis capillaris* (L.) Nees
Uniola latifolia Michx.
Triodia flava (L.) Smyth
Elymus virginicus L. var. *jejunus* (Ramaley) Bush
Elymus virginicus L. var. *glabriflorus* (Vasey) Bush forma *australis* (Scribn. and Ball) Fern.
Elymus villosus Muhl. forma *arkansanus* (Scribn. and Ball) Fern.
Elymus villosus Muhl. forma *villosus*
Elymus canadensis L.
Hordeum pusillum Nutt.
Hystrix patula Moench forma *patula*
Sphenopholis obtusata (Michx.) Scribn.
Danthonia spicata (L.) Beauv.
**Agrostis stolonifera* L. var. *compacta* Hartm.
**Agrostis perennans* (Walt.) Tuckerm. var. *perennans*
**Agrostis hyemalis* (Walt.) BSP var. *tenuis* (Tuckerm.) Gl.
**Cinna arundinacea* L.
Alopecurus carolinianus Walt.
Phleum pratense L.
Muhlenbergia schreberi Gmel.
**Muhlenbergia sobolifera* (Muhl.) Trin.
**Muhlenbergia frondosa* (Poir.) Fern.
**Brachyelytrum erectum* (Schreb.) Beauv.
Leptochloa filiformis (Lam.) Beauv.
Eleusine indica (L.) Gaertn.
**Leersia virginica* Willd.
Digitaria sanguinalis (L.) Scop.
Digitaria ischaemum (Schreb.) Muhl.
**Paspalum ciliatifolium* Michx. var. *ciliatifolium*
**Panicum philadelphicum* Bernh.
Panicum flexile (Gatt.) Scribn.
Panicum dichotomiflorum Michx. var. *dichotomiflorum*
Panicum capillare L. var. *agreste* Gatt.
Panicum capillare L. var. *campestre* Gatt.
Panicum anceps Michx.
**Panicum agrostoides* Spreng. var. *agrostoides*
**Panicum perlongum* Nash.
Panicum depauperatum Muhl. var. *psilophyllum*
**Panicum lanuginosum* Ell. var. *fasciculatum* (Torr.) Fern.
**Panicum lanuginosum* Ell var. *tennesseense* (Ashe) Gl.
**Panicum polyanthes* Schult.
Panicum sphaerocarpon Ell. var. *sphaerocarpon*
Panicum clandestinum L.
Panicum boscii Poir.
Panicum nitidum Lam. var. *ramulosum* Torr.
**Panicum dichotomum* L.
Echinochloa pungens (Poir.) Rydb.
Setaria glauca (L.) Beauv.
**Andropogon scoparius* Michx. var. *scoparius*
Andropogon virginicus L. var. *virginicus*

CYPERACEAE

**Cyperus esculentus* L.
Cyperus ovularis (Michx.) Torr.
**Cyperus strigosus* L.
**Scirpus atrovirens* Willd. var. *georgianus* (Harper) Fern.
Scirpus lineatus Michx.
Carex cephalophora Muhl. var. *mesochorea* (MacKenzie) Gl.
**Carex annectens* (Bickn.) Bickn. var. *annectens*

Carex vulpinoidea Michx.
**Carex normalis* MacKenzie
Carex brevior (Dewey) MacKenzie
Carex umbellata Schk.
Carex laxiflora Lam. var. *blanda* (Dewey) Boott.
**Carex granularis* Muhl.
**Carex grisea* Wahl.
Carex bushii MacKenzie
Carex complanata Torr. & Hook. var. *hirsuta* (Bailey) Gl.
Carex torta Boott.
Carex aquatilis Wahl.
**Carex typhina* Michx.
**Carex artitecta* Mack.

ARACEAE

**Arisaema triphyllum* (L.) Schott. var. *triphyllum*
Arisaema dracontium (L.) Schott.

COMMELINACEAE

**Tradescantia virginiana* L.
Commelina communis L.
Commelina diffusa Burm. f.
**Commelina virginica* L.

JUNCACEAE

Juncus tenuis Willd. forma *williamsii* (Fern.) Hermann
Juncus dudleyi Wieg.
Luzula campestris (L.) DC. var. *multiflora* (Ehrh.) Celak.

LILIACEAE

Allium canadense L.
Nothoscordum bivalve (L.) Britt.
Erythronium albidum Nutt.
**Ornithogalum umbellatum* L.
Smilacina racemosa (L.) Desf.
Polygonatum biflorum (Walt.) Ell.
Trillium recurvatum Beck
**Smilax hispida* Muhl.

DIOSCOREACEAE

**Dioscorea quaternata* (Walt.) Gmel.
Dioscorea villosa L.

AMARYLLIDACEAE

**Hypoxis hirsuta* (L.) Coville
**Agave virginica* L.

IRIDACEAE

Sisyrinchium albidum Raf.

ORCHIDACEAE

Spiranthes gracilis (Bigel.) Beck

SALICACEAE

Populus deltoides Marsh.
Salix nigra L.
Salix sericea Marsh.

JUGLANDACEAE

Juglans nigra L.
**Carya ovata* (Mill.) K. Koch
Carya ovalis (Wang.) Sarg.
Carya cordiformis (Wang.) K. Koch
**Carya tomentosa* (Poir.) Nutt.
Carya buckleyi Durand

BETULACEAE

Corylus americana Walt.
Carpinus caroliniana Walt.
Ostrya virginiana (Mill.) K. Koch
Betula nigra L.

FAGACEAE

Fagus grandifolia Ehrh. var. *caroliniana* (Loud.) Fern & Rehder
Quercus stellata Wang.
Quercus alba L.
Quercus bicolor Willd.
Quercus prinoides Willd. var. *acuminata* (Michx.) Gl.
Quercus imbricaria Michx.
Quercus marilandica Muench.
**Quercus borealis* Michx. f. var. *maxima* (Marsh.) Ashe
Quercus velutina Lam.

ULMACEAE

Ulmus americana L.
Ulmus rubra Muhl.
Ulmus alata Michx.
Celtis laevigata Willd.

MORACEAE

Morus rubra L.

URTICACEAE

Parietaria pensylvanica Muhl.
**Pilea pumila* (L.) Gray

SANTALACEAE

Comandra umbellata (L.) Nutt.

ARISTOLOCHIACEAE

**Asarum canadense* L. var. *reflexum* (Bickn.) Robins
Aristolochia serpentaria L.

POLYGONACEAE

Rumex acetosella L.
**Rumex crispus* L.
Polygonum lapathifolium L. var. *nodosum* (Raf.) Wein.
Polygonum pensylvanicum L. var. *laevigatum* Fern.
Polygonum pensylvanicum L. var. *pensylvanicum*
Polygonum orientale L.
Polygonum punctatum Ell. var. *punctatum*
**Polygonum scandens* L.

CHENOPODIACEAE
**Chenopodium standleyanum* Aellen
**Chenopodium hybridum* L.

AMARANTHACEAE
Amaranthus hybridus L.

PHYTOLACCACEAE
Phytolacca americana L.

PORTULACACEAE
Claytonia virginica L.

CARYOPHYLLACEAE
**Paronychia fastigiata* (Raf.) Fern. var. *fastigiata*
**Cerastium viscosum* L.
**Cerastium vulgatum* L.
Agrostemma githago L.
Silene stellata (L.) Ait. var. *scabrella* (Nieuw.) Palm. & Steyerm.
Silene antirrhina L.
Dianthus armeria L.

MAGNOLIACEAE
**Liriodendron tulipifera* L.

ANNONACEAE
Asimina triloba (L.) Dunal

RANUNCULACEAE
Hydrastis canadensis L.
**Actaea alba* (L.) Mill. forma *rubracarpa* (Killip.) Fern.
Isopyrum biternatum (Raf.) Torr. & Gray
Ranunculus abortivus L. var. *abortivus*
Ranunculus harveyi (Gray) Britt.
**Ranunculus recurvatus* Poir.
**Ranunculus hispidus* Michx. var. *hispidus*
Anemone virginiana L.
**Anemonella thalictroides* (L.) Spach

BERBERIDACEAE
**Podophyllum peltatum* L.

MENISPERMACEAE
Menispermum canadense L.

LAURACEAE
Sassafras albidum (Nutt.) Nees
Lindera benzoin (L.) Blume

PAPAVERACEAE
Sanguinaria canadensis L. var. *rotundifolia* (Greene) Fedde

FUMARIACEAE
Corydalis flavula (Raf.) DC.

CRUCIFERAE
Lepidium virginicum L. var. *virginicum*
Capsella bursa-pastoris (L.) Medic.
Draba verna L.
Draba brachycarpa Nutt.
**Cardamine pensylvanica* Muhl.
Dentaria laciniata Muhl.
Arabis laevigata (Muhl.) Poir.
Barbarea vulgaris R. Br.
Arabidopsis thaliana (L.) Heyn.

SAXIFRAGACEAE
**Heuchera parviflora* Bartl. var. *rugelii* (Shuttlw.) R. B. & L.
Heuchera hirsuticaulis (Wheelock) Rydb.
Hydrangea arborescens L. var. *arborescens*
Ribes missouriense Nutt.

PLATANACEAE
Platanus occidentalis L.

ROSACEAE
**Aruncus dioicus* (Walt.) Fern. var. *pubescens* (Rydb.) Fern.
**Gillenia stipulata* (Muhl.) Trel.
**Potentilla simplex* Michx.
Geum canadense Jacq.
**Rubus ostryifolius* Rydb.
Rubus enslenii Tratt.
**Agrimonia rostellata* Wallr.
**Agrimonia pubescens* Wallr.
Rosa setigera Michx. var. *tomentosa* T. & G.
Rosa carolina L.
**Prunus serotina* Ehrh.
**Prunus munsoniana* Wight and Hedrick
**Crataegus coccinioides* Ashe
Amelanchier arborea (Michx. f.) Fern.

CAESALPINIACEAE
Cercis canadensis L.
Gleditsia triacanthos L.
**Gymnocladus dioica* (L.) K. Koch
Cassia fasciculata Michx. var. *fasciculata*

FABACEAE
Crotalaria sagittalis L.
Trifolium pratense L.
Trifolium repens L.
Trifolium hybridum L.
**Trifolium procumbens* L.
Melilotus alba Desr.
Medicago lupulina L.
Psoralea psoralioides (Walt.) Cory var. *eglandulosa* (Ell.) Freeman

Apios americana Medic.
Petalostemum candidum (Willd.) Michx.
Tephrosia virginiana (L.) Pers.
**Desmodium nudiflorum* (L.) DC.
**Desmodium canescens* (L.) DC.
**Lespedeza procumbens* Michx.
Lespedeza repens (L.) Bart.
Lespedeza violacea (L.) Pers.
Lespedeza virginica (L.) Britt.
**Lespedeza hirta* (L.) Hornem. var. *hirta*
Stylosanthes biflora (L.) BSP. var. *biflora*
Amphicarpa bracteata (L.) Fern. var. *bracteata*
Strophostyles leiosperma (T. & G.) Piper
**Strophostyles helvola* (L.) Ell.

OXALIDACEAE

Oxalis stricta L.
Oxalis europaea Jord.
Oxalis violacea L. var. *trichophora* Fassett

GERANIACEAE

Geranium carolinianum L.
Geranium maculatum L.

POLYGALACEAE

Polygala verticillata L. var. *sphenostachya* Pennell

EUPHORBIACEAE

Croton glandulosus L. var. *septentrionalis* Muell.-Arg.
Croton capitatus Michx. var. *capitatus*
**Acalypha rhomboidea* Raf.
Acalypha virginica L.
**Acalypha gracilens* Gray
Euphorbia maculata L.
Euphorbia corollata L.
**Euphorbia marginata* Pursh.

CALLITRICHACEAE

Callitriche deflexa A. Br. var. *austinii* (Engelm.) Hegelm.

ANACARDIACEAE

Rhus radicans L. var. *vulgaris* (Michx.) DC.
Rhus aromatica Ait.
Rhus glabra L. var. *glabra*
Rhus copallina L.

AQUIFOLIACEAE

Ilex decidua Walt.

STAPHYLEACEAE

**Staphylea trifolia* L.

ACERACEAE

**Acer barbatum* Michx.
Acer negundo L. var. *negundo*
Acer saccharum Marsh var. *saccharum*
Acer rubrum L.

BALSAMINACEAE

Impatiens biflora Walt.

RHAMNACEAE

Ceanothus americanus L. var. *pitcheri* T. & G.

VITACEAE

**Vitis cinerea* Engelm. var. *cinerea*
**Vitis lincecumii* Buckl.
Vitis vulpina L.
Parthenocissus quinquefolia (L.) Planch. var. *saint-paulii* (Graebn.) Rehd.

MALVACEAE

Sida spinosa L.

HYPERICACEAE

**Ascyrum hypericoides* L. var. *multicaule* (Michx.) Fern.
**Hypericum sphaerocarpum* Michx. var. *sphaerocarpum*
Hypericum punctatum Lam.
Hypericum mutilum L. var. *parviflorum* (Willd.) Fern.
Hypericum gentianoides (L.) BSP
Hypericum drummondii (Grev. & Hook.) T. & G.

CISTACEAE

Lechea tenuifolia Michx.

VIOLACEAE

Viola pedata L. var. *pedata*
**Viola papilionacea* Pursh
Viola sororia Willd.
Viola triloba Schw. var. *dilatata* Ell.
**Viola eriocarpa* Schw.
Viola rafinesquii Green
**Viola striata* Ait.

PASSIFLORACEAE

**Passiflora lutea* L. var. *glabriflora* Fern.

LYTHRACEAE

Ammannia coccinea Rothb.

ONAGRACEAE

**Ludwigia glandulosa* Walt.
**Ludwigia alterniflora* L.
Oenothera biennis L.
Oenothera laciniata Hill
**Oenothera pilosella* Raf.
Oenothera linifolia Nutt.
**Circaea quadrisulcata* (Maxim.) Franch. and Sav. var. *canadensis* (L.) Hara

UMBELLIFERAE

Sanicula canadensis L. var. *canadensis*
**Sanicula gregaria* Bickn.
**Erigenia bulbosa* (Michx.) Nutt.
Cryptotaena canadensis (L.) DC.
Cicuta maculata L. var. *maculata*
**Thaspium trifoliatum* (L.) Gray

CORNACEAE

Cornus florida L.
Cornus racemosa Lam.
**Nyssa sylvatica* Marsh var. *caroliniana* (Poir.) Fern.

ERICACEAE

Vaccinium arboreum Marsh.
Vaccinium vacillans Torr.

PRIMULACEAE

**Dodecatheon meadia* L.
Samolus floribundus HBK.

EBENACEAE

Diospyros virginiana L. var. *virginiana*

OLEACEAE

**Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl) Fern.
Fraxinus americana L.

GENTIANACEAE

**Obolaria virginica* L.

APOCYNACEAE

**Apocynum cannabinum* L. var. *cannabinum*
Apocynum cannabinum L. var. *pubescens* (Mitchell) A. DC.

ASCLEPIADACEAE

Asclepias tuberosa L.
Asclepias verticillata L.
**Asclepias exaltata* L.
Ampelamus albidus (Nutt.) Britt.

CONVOLVULACEAE

Ipomoea lacunosa L.
**Cuscuta cephalanthi* Engelm.
**Cuscuta gronovii* Willd.

POLEMONIACEAE

Phlox divaricata L.
Phlox bifida Beck
Polemonium reptans L.

BORANGINACEAE

Lithospermum canescens (Michx.) Lehm.
Lithospermum arvense L.
Myosotis virginica (L.) BSP.
Myosotis micrantha Pall.
Cynoglossum virginianum L.
**Hackelia virginiana* (L.) Johnst.
Mertensia virginica (L.) Pers.

VERBENACEAE

Verbena urticifolia L. var. *urticifolia*

LABIATAE

Teucrium canadense L. var. *canadense*
Scutellaria incana Biehler var. *incana*
Scutellaria parvula Michx.
**Glecoma hederacea* L. var. *parviflora* (Benth.) Druce
Prunella vulgaris L. var. *vulgaris*
Prunella vulgaris L. var. *lanceolata* (Bart.) Fern.
Monarda bradburiana Beck
Hedeoma pulegioides (L.) Pers.
Pycnanthemum flexuosum (Walt.) BSP.
Cunila origanoides (L.) Britt.
**Lycopus americanus* Muhl. var. *longii* Benner

SOLANACEAE

Solanum nigrum L. var. *vulgare* L.
Solanum carolinense L.

SCROPHULARIACEAE

Leucospora multifida (Michx.) Nutt.
**Mimulus alatus* Ait.
Verbascum thapsus L.
Penstemon pallidus Small
Penstemon calycosus Small
Veronica peregrina L. var. *xalapensis* (HBK.) Pennell
**Aureolaria grandiflora* (Benth.) Pennell
**Aureolaria flava* (L.) Farw.
Gerardia tenuifolia Vahl var. *tenuifolia*

BIGNONIACEAE

**Catalpa bignonioides* Walt.
Campsis radicans (L.) Seem.

ACANTHACEAE

Ruella humilis Nutt. var. *expansa* Fern.
Ruellia pedunculata Torr.
Ruellia strepens L.
Justicia americana (L.) Vahl

PHRYMACEAE

Phryma leptostachya L.

PLANTAGINACEAE

Plantago rugelii Dcne.
Plantago pusilla Nutt.
Plantago virginica L.
Plantago aristata Michx.

RUBIACEAE

Houstonia tenuifolia Nutt.
Houstonia patens Ell.
Houstonia longifolia Gaertn.
**Mitchella repens* L.
**Diodea teres* Walt.
Cephalanthus occidentalis L.
Galium circaezans Michx.
**Galium aparine* L.
**Galium pilosum* Ait.
Galium concinnum Torr. & Gray

CAPRIFOLIACEAE

Sambucus canadensis L. var. *submollis* Rehder

VALERIANACEAE

Valerianella radiata (L.) Dufr.

CAMPANULACEAE

Specularia perfoliata (L.) A. DC.

LOBELIACEAE

**Lobelia siphilitica* L. var. *siphilitica*
**Lobelia puberula* Michx.
**Lobelia inflata* L.

COMPOSITAE

Eclipta alba (L.) Hassk.
Rudbeckia hirta L.
Rudbeckia triloba L. var. *triloba*
Bidens aristosa (Michx.) Britt.
Bidens coronata (L.) Britt.
**Bidens vulgata* Green var. *vulgata*
**Polymnia canadensis* L.
**Silphium integrifolium* Michx.
Silphium perfoliatum L.
Ambrosia bidentata Michx.
Ambrosia trifida L.
Ambrosia artemisiifolia L.
**Helenium nudiflorum* Nutt.
**Anthemis nobilis* L.
Achillea millefolium L.
Matricaria chamomilla L.
Senecio glabellus Poir.
Cacalia atriplicifolia L.
Solidago nemoralis Ait. var. *nemoralis*
Solidago caesia L.
Solidago buckleyi Torr. & Gray
Solidago ulmifolia Muhl. var. *ulmifolia*
Solidago rugosa Mill.
**Solidago gigantea* Ait. var. *leiophylla* Fern.
Solidago altissima L.
**Aster sagittifolius* Willd.
**Aster patens* Ait. var. *potentissimus* (Lindl.) T. & G.
Aster pilosus Willd.
**Aster turbinellus* Lindl.
Aster lateriflorus (L.) Britt.
**Aster simplex* Willd. var. *interior* (Wieg.) Cron.
Erigeron strigosus Muhl. var. *strigosus*
Erigeron annuus (L.) Pers. var. *annuus*
Conyza canadensis (L.) Cron. var. *canadensis*
**Antennaria plantaginifolia* (L.) Richards var. *plantaginifolia*
Antennaria plantaginifolia (L.) Richards var. *arnoglossa* (Green) Cron.
Gnaphalium purpureum L.
Gnaphalium obtusifolium L.
Eupatorium serotinum Michx.
Eupatorium rugosum Houtt.
Eupatorium coelestinum L.
Vernonia missurica Raf.
Elephantopus carolinianus Willd.
Prenanthes altissima L. var. *cinnamomea* Fern.
**Hieracium gronovii* L.
Lactuca scariola L.
**Lactuca canadensis* L. var. *canadensis*
**Lactuca floridana* (L.) Gaertn.
Krigia dandelion (L.) Nutt.
Krigia biflora (Walt.) Blake
**Krigia oppositifolia* Raf.

DISCUSSION

Over a period of forty-four weeks the author collected 441 taxa in the region of Piney Creek Ravine, among which were 136 not previously recorded from Randolph County. Moreover, twenty-nine of the taxa are considered to be of unusual occurrence at Piney Creek and are here placed into two categories.

The first of these contains twenty taxa which are of rare occurrence within the study area and are at the same time considered rare elements in the flora of southern Illinois. This group includes the following taxa:

Asplenium trichomanes
Poa paludigena
Carex annectens
Carex normalis
Carex torta
Carex aquatilis
Commelina communis
Commelina virginica
Spiranthes gracilis
Cerastium viscosum
Vitis lincecumii
Passiflora lutea var. *glabriflora*
Ludwigia glandulosa
Obolaria virginica
Asclepias exaltata
Mitchella repens
Silphium integrifolium
Solidago buckleyi
Solidago rugosa
Aster turbinellus

The second of these categories contains those species which are of common or occasional occurrence at Piney Creek, but are considered rare in other areas of southern Illinois. Included in this group are the following nine taxa:

Pinus echinata
Bromus ciliatus var. *intonsus*
Panicum perlongum
Carex umbellata
Salix sericea
Ranunculus harveyi
Viola pedata
Asplenium bradleyi
Agave virginica

Generally speaking, five plant communities may be recognized in the area immediately adjacent to Piney Creek. The following is a designation and brief description of each of these, including a listing of some of the plants most commonly found in them.

Exposed Dry Bluff Community

The tops of bluffs throughout the area, particularly near the source of Piney Creek, are mostly exposed sandstone, although a number of these areas is covered by a very thin layer of fine soil. Growing in this exposed situation is a vegetation that is predominantly xerophytic and usually exhibits the entire successional history of the bluff.

Lichens and mosses are characteristic near the edges of the bluffs and contribute to the accumulation of soil. As a thin layer of soil is built up further back, a variety of shallow rooted herbs, such as *Festuca octoflora, Poa chapmaniana,* and *Plantago pusilla,* become established. Next in the line of successional stages may be observed the shrub zone, well represented by farkleberry (*Vaccinium arboreum*), highbush blueberry (*Vaccinium vacillans*), and fragrant sumac (*Rhus aromatica*). This stage finally gives way to a scrub oak type of vegetation composed almost entirely of post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), red cedar (*Juniperus virginiana*), and winged elm (*Ulmus alata*). Throughout this community a number of herbaceous species occur, most of which are summer flowering species characteristic of rocky surfaces. These include *Tephrosia virginiana, Stylosanthes biflora, Agave virginica, Viola pedata, Phlox bifida,* and *Hypericum gentianoides.* Also characteristic of the area are a large number of grass species, as well as the hairy lipfern (*Cheilanthes lanosa*).

Below the margins of these bluff tops are many dry, rocky ledges which provide a microhabitat suitable for Bradley's spleenwort (*Asplenium bradleyi*). This fern is very characteristic of Piney Creek, although its occurrence is infrequent in similar situations in other parts of Illinois.

Dry Slope Community

The most extensive plant cover in the Piney Creek area is found on the dry slopes adjacent to sandstone bluffs. Seemingly intermediate between the mesophytic ravine forests and the exposed dry bluff community, these hillside slopes are predominantly of an oak-hickory composition. They are characterized by an almost homogeneous aggregation of white oak (*Quercus alba*), black oak (*Quercus velutina*), red oak (*Quercus borealis*), bitternut hickory (*Carya cordiformis*), and small-fruited hickory (*Carya ovalis*). Although not one of the dominant species, the shortleaf pine (*Pinus echinata*) is also characteristic of this community at Piney Creek. Those shrubs most abundant in the understory are the shadbush (*Amelanchier arborea*) and the flowering dogwood (*Cornus florida*). Of the herbaceous species found here, fewer flower in the spring than in the summer and autumn. One of the earliest of these non-woody plants to flower is Harvey's buttercup (*Ranunculus harveyi*). It is one of the most notable plants of the area because, although it is rare in Illinois, it is very abundant in the area of Piney Creek.

Mesophytic Ravine Community

As Piney Creek descends from its source, it passes through a narrow, high-walled valley that eventually widens into a lowland with many slightly elevated areas between high bluffs and steep slopes. Dispersed within this are are numerous boulders, separated from the face of the bluff through many years of gradual erosion. Favorable environmental conditions have allowed for the development of a relatively rich community and it is in these mesic woodland ravines that the most luxurious vegetation of Piney Creek is found. Here are locations which exhibit rapid succession into excellent forest lands because of favorable soil-moisture conditions.

In these lowlands between the bluffs occur forests of beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), southern sugar maple (*Acer barbatum*), and tulip tree (*Liriodendron tulipifera*). On slightly elevated areas sour gum (*Nyssa sylvatica*) and species of hickory (*Carya spp.*) become important along with sugar maple. Characteristic shrubs are spicebush (*Lindera benzoin*), blue beech (*Carpinus caroliniana*), and hop hornbeam (*Ostrya virginiana*). The herbaceous plants consist of a large variety of grasses, sedges, and other flowering plants which are mostly vernal in their flowering aspect.

On vertical walls and ledges at the base of the bluffs, and on boulders separated from them, are many varieties of mosses and liverworts in addition to some flowering plants requiring moist, shaded habitats. Two plants of unusual occurrence in southern Illinois grow in this situation at Piney Creek and should be mentioned. One is sphagnum moss (*Sphagnum capillaceum*), characteristic of sphagnum bogs of the north; the other is the partridge berry (*Mitchella repens*), also with a northern affinity.

Stream Bank Community

Along the banks of Piney Creek is found a very distinct community characterized by such trees as black willow (*Salix nigra*), cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), and red maple (*Acer rubrum*). Typical herbaceous species to be found in the gravelly beds and sandy shores of Piney Creek are *Commelina virginica, Hypericum mutilum, Lobelia cardinalis, Lobelia siphilitica, Justicia americana, Dianthus armeria, Equisetum hyemale, Bidens coronata, Polygonum lapathifolium, Polygonum pensylvanicum,* numerous grasses, and a few sedges. One sedge, *Carex torta,* is very common in this area, but is uncommon elsewhere in Illinois. Near the mouth of Piney Creek is found a single patch of giant cane (*Arundinaria gigantea*). Here it is so abundant that it forms a dense thicket.

Waste Ground Community

Roadsides, pastures, and abandoned fields constitute three temporary situations, all in such proximity to Piney Creek that they were included in the study of this area and were grouped together into the waste ground community. A large number of the weeds in the area, a few species of previous cultivations, and a variety of species native to the region normally become established on such sites. Woody species most commonly found on these sites include such examples as sassafras (*Sassafras albidum*), trumpet creeper (*Campsis radicans*), catalpa (*Catalpa bignonioides*), persimmon (*Diospyros virginiana*), smooth sumac (*Rhus glabra*), dwarf sumac (*Rhus copallina*), blackberries (*Rubus spp.*), and wild rose (*Rosa carolina*). These plants are not considered dominants here for in these areas the vegetation lacks the structure or organization found in older stabilized associations.

After further consideration of the taxa recorded for the area of this investigation, it was evident that a few of the plants collected have affinities characteristic of other areas of the United States. Thus, another aspect of this paper is an attempt to explain the occurrence of some of these plants at Piney Creek.

When small colonies or single individuals of plants are found within an area that belong to some more distant formation, they are usually referred to as relics (Braun, 1928). Examples of such relics are frequently found near the southern boundary of continental glaciation where vegetation was affected either directly or indirectly by the changing climate.

Since Piney Creek lies just north of the southern boundary of Illinoian glaciation, and since some of the plants here are not successionally related to the surrounding vegetation, it is necessary to consider them in the light of past migrations of the glacial epoch and early postglacial period.

During Pleistocene times a series of glacial advancements and recessions occurred several times, with the third advance reaching its southern limit in Illinois, a few miles

south of Piney Creek. This advance is known as the Illinoian glacier and during the early interglacial period that followed, Piney Creek and the surrounding areas of southern Illinois probably were almost entirely covered with a northern type forest. However, as the glacier receded northward, the vegetation of preglacial times became re-established in the glaciated area, with the exception of a few of these northern plants which remained in peculiarly protected or favored spots.

Most notable of these at Piney Creek are two species of the Bryophyta. One, *Sphagnum capillaceum,* occurs a short distance below the source of Piney Creek. Here it forms a large colony on a north-facing slope just above a moist sandstone ledge. In this situation there is a seepage of water between the soil and the bedrock creating a very hydrophytic condition. Since sphagnum is characteristic of bogs in colder climates to the north, the accumulation of moisture from seepage is evidently necessary for this species to continue to exist here.

Growing in association with this sphagnum moss, another relic bryophyte can be found. This species is a leafy hepatic. However, because of the sterile condition of the specimen collected, its determination was limited to a choice of two species. This choice was between *Cephaloziella subdentata* or *C. elachistata,* and was determined by R. E. MacMahon and later verified by R. M. Schuster. Schuster (1953) describes *C. elachistata* as "widely distributed throughout the Coniferous Region, becoming rare in isolated bogs in the northern edge of the Deciduous Zone." As for *C. subdentata* he writes: "It is closely allied to *C. elachistata,* but has an essentially more northern largely Arctic-Alpine range." Thus the specimen discovered at Piney Creek is definitely northern in its distribution. Further study of the bryophytes in this area would perhaps be of great value, for these plants with their micro-environmental requirements might contribute more to the study of glacial distribution than the vascular plants which are less likely to remain in a suitable environment and therefore appear as glacial relics.

Besides these plants of northern affinity, many plants of southern and southeastern distribution reach their northwestern limit within the deep ravines and atop the high bluffs at Piney Creek. Examples of these are: *Pinus echinata, Agave virginica, Asplenium bradleyi, Arundinaria gigantea, Panicum agrostoides,* and *Obolaria virginica.*

During the Pleistocene Epoch, vegetation was forced southward and became concentrated in the Southern United States. Following recession of the glacier, plants subsequently migrated northward again from a center of distribution believed to be the Southern Appalachians (Cain, 1930).

With regard to the migration of these plants from the south, Braun (1928) noted that certain species have reached a northern limit in their dispersal at the southernmost glacial boundary. As an explanation she comments that these plants may belong to one of three categories: (1) plants which have reached their northern climatic lim-

it; (2) plants still migrating, which have not had time to spread far across the glacial boundary; and (3) passive species restricted in range by glaciation, and not showing any disposition to spread. She goes on to say that *Pinus echinata* probably belongs in the second category, whereas *Agave virginica* may be one of the species in the third group.

It is interesting to note that many of the southern species listed at Piney Creek are also a very characteristic part of the Missouri Ozark flora. Examples of these are *Pinus echinata, Commelina virginica, Celtis laevigata, Vaccinium arboreum, Ilex decidua, Oenothera linifolia, Asplenium bradleyi, Ruellia pedunculata,* and *Eupatorium coelestinum.*

In contrast to the opinion that the southern United States was the center of origin for these species, Palmer and Steyermark (1935) have quite an opposite point of view. They present the possibility that these species may have persisted in the Ozark region since pre-glacial times, for this area has been a continuous land surface since late Paleozoic. If this is true, the possibility should not be overlooked that some of these species, as well as others, may have been developed in the Ozark region and may have been dispersed from this center. In their arguments supporting this possibility, they presented the idea that it is highly unlikely that extensive immigration could have taken place from the southeast after the development of wide floodplains of the Mississippi River, for this offers an effective barrier to many upland species.

Whether or not this point of view is correct, the Ozarks seem to be an important contributor to the Piney Creek flora. Other species, such as *Viola pedata* and *Ranunculus harveyi,* show no southern affinity, although they are characteristic members of both the Missouri Ozark and Piney Creek regions. Of further significanec is the fact that Mill Creek, of which Piney Creek is a tributary, is similar in many respects to the topography of the Ozarks and also supports many of the same species.

Although the Mississippi Valley may serve as a barrier to the spread of many upland species across the great expanse of floodplain from the Appalachians to the Ozarks, it may not prevent the migration of these plants in other areas where the floodplains of the Mississippi are not as wide. Thus it seems possible that many species have crossed the relatively short distance from the Missouri Ozarks to bluffs on the Illinois side of the river. Here they continued to migrate along bluffs that were formed by tributaries of the Mississippi and have become established in Ozark-like areas such as Piney Creek.

Summary

Over a period of 44 weeks, 441 taxa were collected in the region of Piney Creek Ravine, including 136 Randolph County records. After a general survey of the plant communities of this area, a more specific study of each of its individual elements was made. As a result of this, the following conclusions were drawn with regard to the plants of Piney Creek.

(1) Consideration of the vegetation of Piney Creek with regard to the geographic distribution of each species collected made apparent the fact that a number of the taxa present in these communities have affinities characteristic of other areas of the United States. These were explained in three ways.

(a) Those plants showing northern affinities probably were brought into the area under compulsion of continental glaciation and left as relic species. Examples of such plants are *Sphagnum capillaceum* and *Cephaloziella subdentata*, or *C. elachistata*.

(b) Many other species found at Piney Creek are plants which appear to have reached a northern limit in their dispersal from a southern or southeastern center of distribution. Braun (1928) has offered possible explanations concerning this restriction in distribution.

(c) Finally, quite a number of taxa represented in the flora of Piney Creek were found to be very characteristic of the Ozarks of Missouri. Palmer and Steyermark (1935) presented the idea that many of these species probably had their center of origin in the Ozarks because of its long period of continuous land surface. They support this idea with the assumption that the wide floodplains of the Mississippi Valley between the southeastern United States and the Ozarks of Missouri have served as a barrier to the spread of many upland species. Therefore, extensive immigration could not have taken place from the east. However, this author believes that because of the relative proximity of the Missouri Ozarks to southern Illinois, many of these species may have continued to migrate and have become established in areas such as Piney Creek.

(2) Of a more specific nature, some species collected at Piney Creek were placed into special categories regarding their occurrences there. These include plants rare to Piney Creek as well as other areas of southern Illinois and plants common or occasional in occurrence at Piney Creek, but rare elsewhere in southern Illinois.

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MAJOR HAILSTORMS RETRACE TRI-STATE TORNADO TRACK IN ILLINOIS

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ABSTRACT. — Two adjacent very damaging hailstorms in March 1967 occurred exactly along a portion of the famous Tri-state tornado that crossed southern Illinois 42 years earlier. This enormous 3-hour tornado killed 606 persons in Illinois and has left a still-evident and inordinate fear of severe weather in many older citizens of that area. The 2 hailstorms occurred in a dense weather-observation network and added storm data came from a field survey. The storms occurred in a 31-minute period and 3-inch diameter hailstones resulted. The tendency of a populace to remember very severe weather events through 1 or more generations has been evident over the past 200 years, but it may be changing due to the continuous exposure by news media to information on worldwide severe weather disasters.

It has been observed that many older residents of southern Illinois cities and towns devastated by the famous Tri-state tornado of 18 March 1925 exhibit more than normal apprehension when severe thunderstorms approach. The Tri-state tornado began in southeastern Missouri and moved northeastward across southern Illinois and into Indiana along a nearly straight path of 219 miles (longest on record) at a near-record average speed of 62 mph (Changnon and Semonin, 1966). During most of its 3.5-hour lifetime it produced a damage path 1 mile wide, and caused the deaths of 695 persons (606 in Illinois), injuries to 2,027, and damages totaling $40 million (in 1964) dollars.

The terrible lesson learned by area residents in 1925—that a tornado funnel could be hidden from view because of its huge width, closeness to the ground, and preceding veil of dust and low clouds—causes the local residents, particularly those of age 55 years or older, to be inordinately fearful of similar dark, low-based thunderstorms.

The reaction of local residents and the news media to a severe hailstorm day in 1967 that occurred along a portion of the 1925 tornado track almost exactly 42 years later reveals this tornado memory and the fear that still lingers in this area of Illinois.

The oddity of a second series of severe storms along the same track of the 1925 tornado is of considerable interest to meteorologists and climatologists. These hailstorms were the subject of a detailed meteorological study, and some of the pertinent findings are presented in this paper. The other reason for this paper is to describe the effect of a severe weather event on the memory and attitudes of those experiencing the event, and to speculate as to types of severe weather events that may be retained in regional memories for more than just a few years.

Description of 12 March 1967 Hailstorms

A dense raingage network comprising 49 gages in a 550-square-mile area was established in 1957 in southern Illinois by the Illinois State Water Survey to make various climatological and meteorological studies of rainfall (Changnon, 1963; Huff and Changnon, 1966). This square-shaped network with its uniform array of standard raingages (Fig. 1) was centered on West Frankfort, one of the two cities that experienced major losses from the Tri-state tornado.

As a part of the multiple hail studies being sponsored by the Atmospheric Sciences Section of the National Science Foundation (NSF GA-482), several severe hailstorms during 1967 were field-studied in detail (Changnon, 1968a). Results of these studies of 1967 storms and others similarly investigated in 8 prior years were the subject of a recent paper dealing with modeling of severe hailstorms (Changnon,

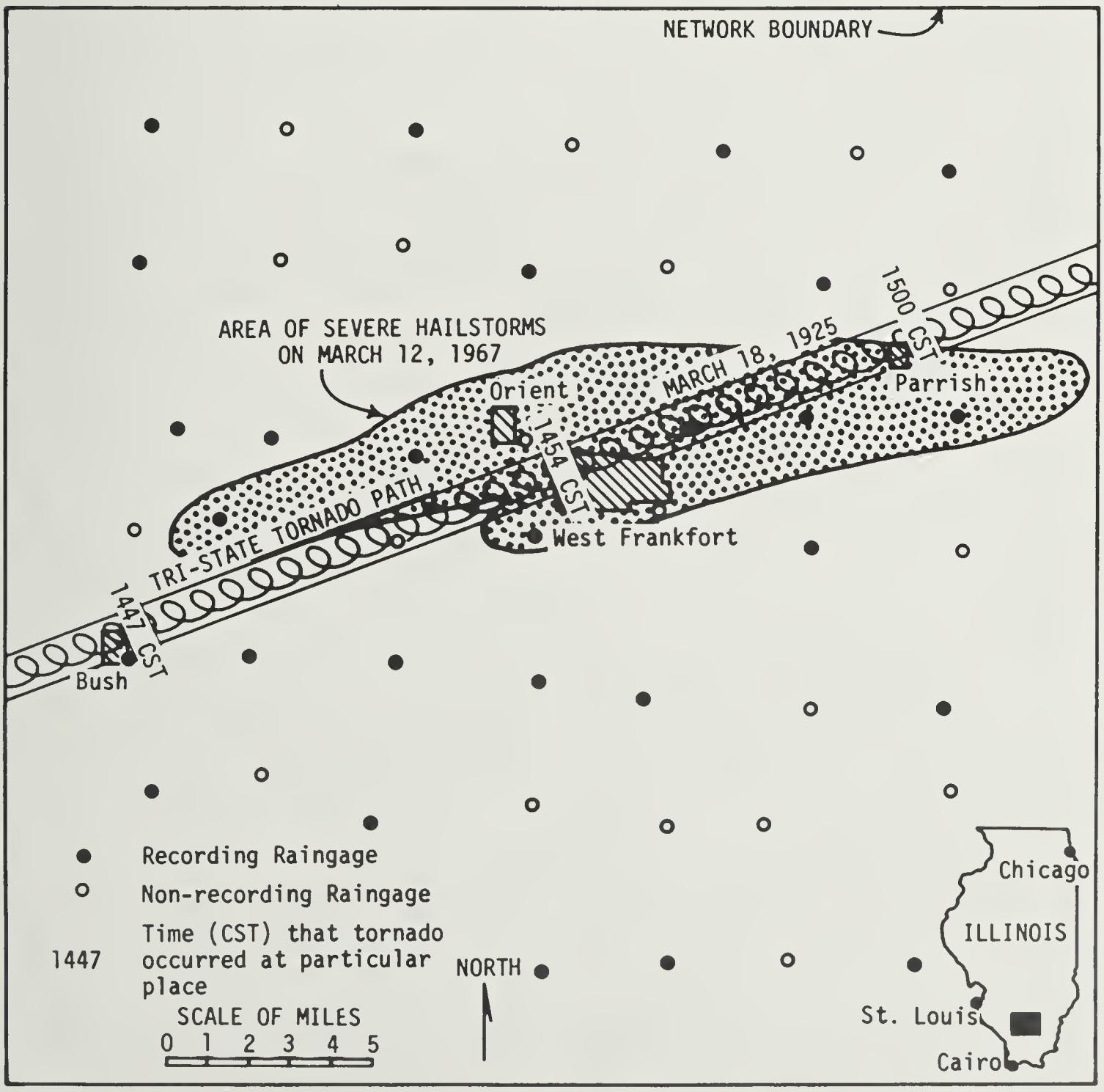


Figure 1. Storm Areas and Raingage Network in Southern Illinois.

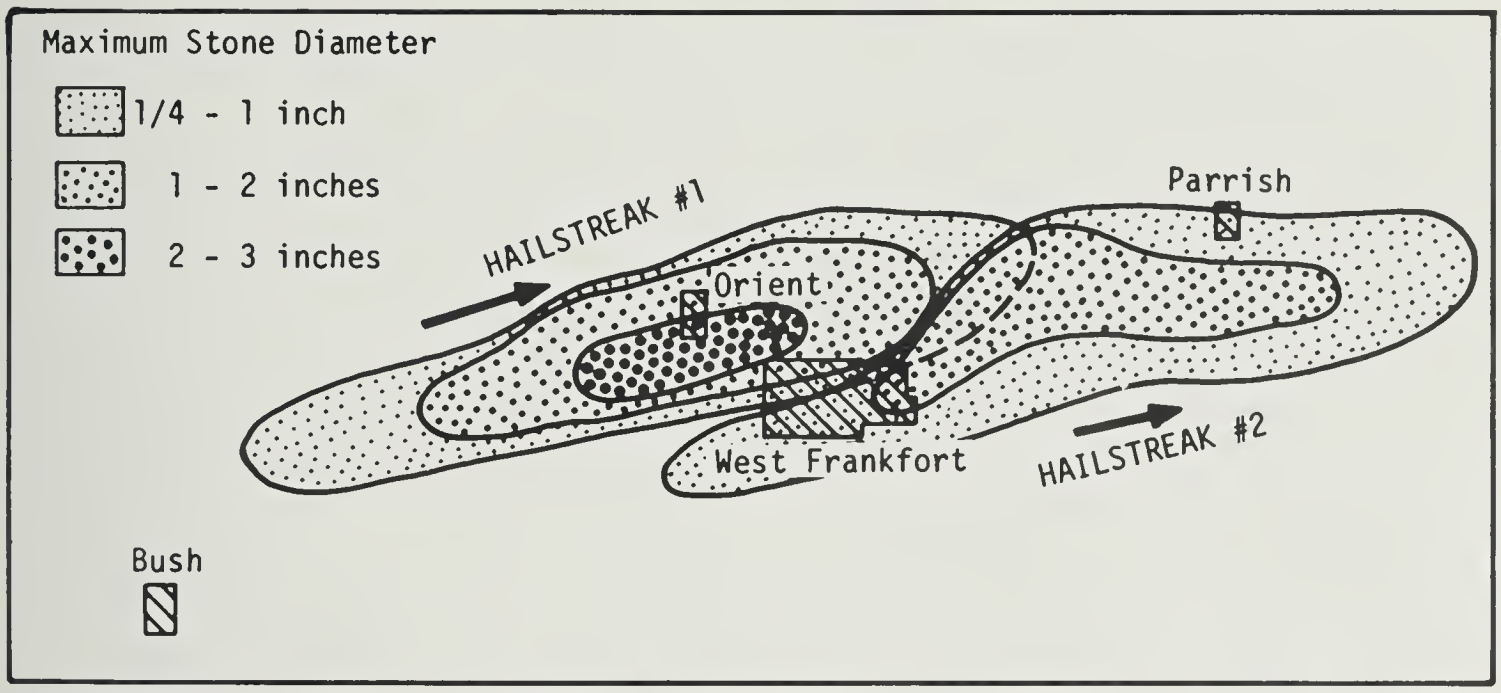
1968b). The occurrence of two of the 1967 severe storms in a dense raingage network was scientifically providential, since the cooperating observers at the non-recording raingages had been asked to report hailfalls in detail. Also, the recording raingages had been modified to record hailfalls (Changnon, 1966), and the recording raingage data allowed determination of the rainfall produced by the hailstorms. A field man, responsible for the weekly servicing of the network's recording raingages, made a detailed field survey in the area encompassed by the two 1967 storms (Fig. 1). He obtained point data on time and size of hailfalls for 33 locations after interviewing 85 persons. These data, plus those from the recording raingages and cooperative observers, were used to reconstruct the surface patterns of the two hailstorms that together produced hail over 73 square miles (Fig. 1).

On the afternoon of 12 March, an east-west stationary front lay across south-central Illinois with storm-producing low centers (waves) moving eastward along this frontal zone. Afternoon surface temperatures in the portion of Illinois south of the front (including the network area) were in the 78° to 83° range, whereas those north of the front were in the 55° to 65° range. Moist Gulf air was moving into the region, and a situation quite conducive to severe spring thunderstorms existed throughout southern Illinois.

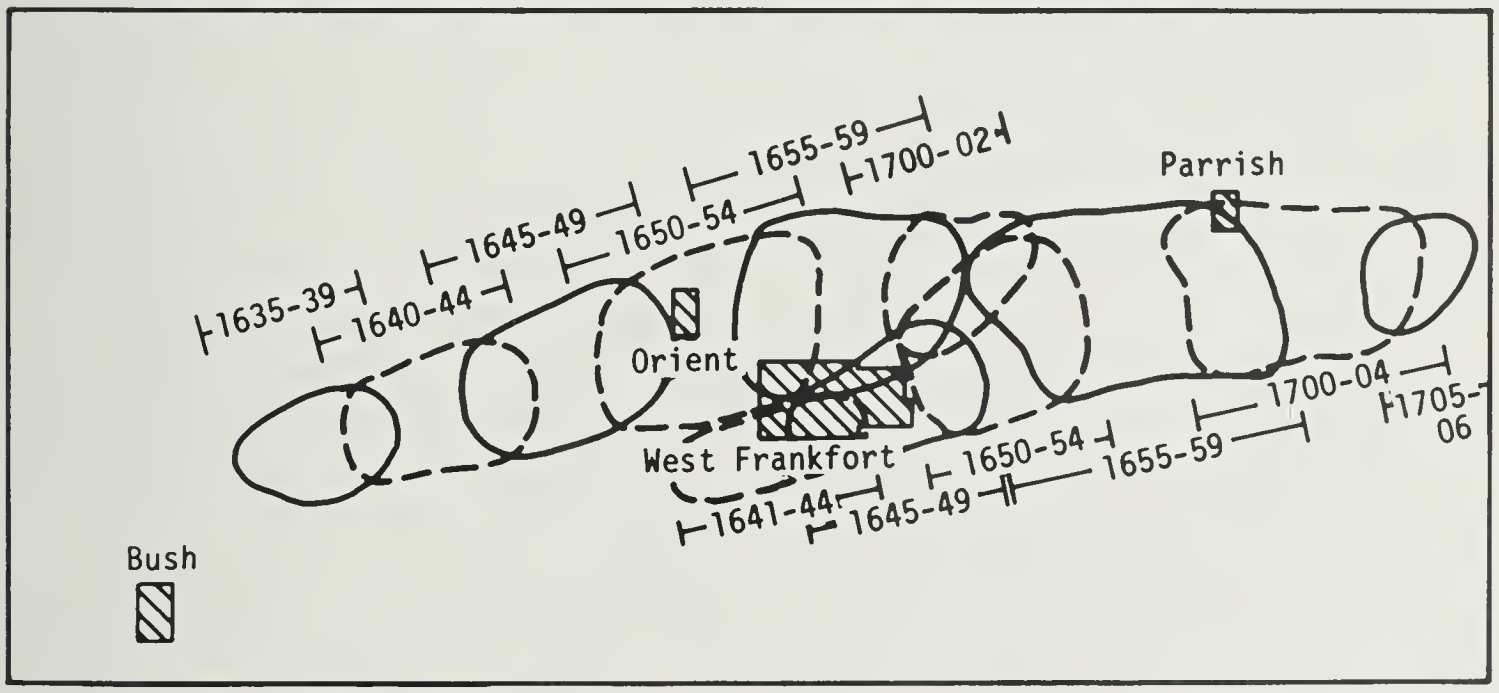
Six eastward-moving thunderstorms occurred in the network during the 1630-1830 CST period, and three of these produced hail. The second and third (as defined by time) thunderstorms developed over the network and each produced severe and widespread hail along paths that were adjacent and partially overlapping. The two paths of continuous hail, labeled as hailstreaks, are shown in Fig. 2a, which also depicts hail areas based on the diameters of the largest hailstone sizes.

Hailstreak number 1 began at 1635 CST and terminated at 1702 CST with a forward speed of 31 mph. Its length was nearly 14 miles and its maximum width was 3.1 miles. Most of the property experiencing 1-inch or larger stones was damaged to some extent, and within the 2- to 3-inch stone area (Fig. 2a) damages to automobiles and homes were excessive.

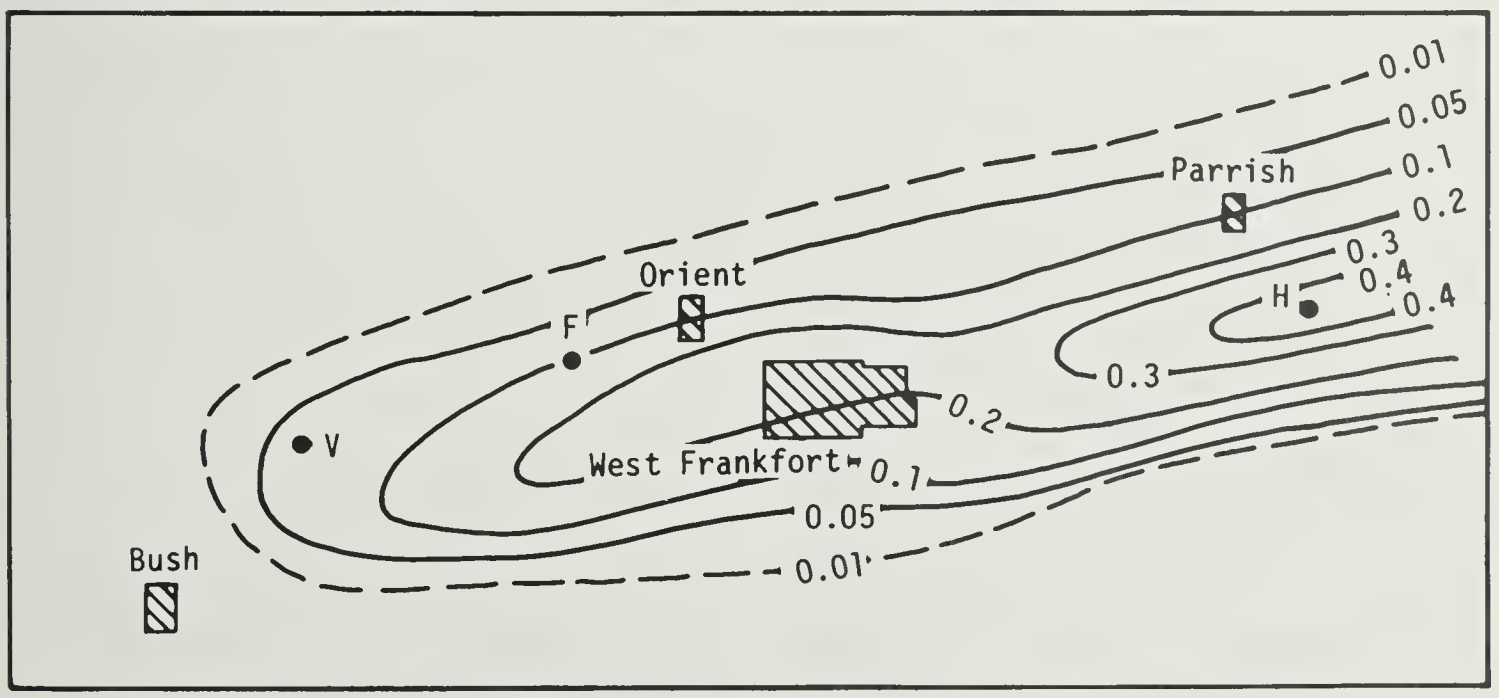
Hailstreak number 2 began at 1641 CST (after hailstreak number 1 had been in progress for 6 minutes, note Fig. 2b) and lasted until 1706 CST. It had an average forward speed of 37 mph, a length of 15 miles, and a maximum width of 3.1 miles, thus closely matching the surface characteristics of the other hailstreak. The largest stones from the second hailstreak were 1.5 inches in diameter, and some property damages resulted in the area defined by these stones. At most points, the hailfalls from each storm lasted 2 to 4 minutes. People in the area experiencing 2- to 3-inch stones reported a loud whistling or hissing roar sound that has been heard in other large hailstorms (Changnon, 1960). This was likely an aerodynamic sound created by the rapidly falling large hailstones, rather than that from a funnel aloft. No evidence of a tornado could be found.



a. Hailstreaks and stone sizes



b. 5-minute hailfall areas



c. Isohyetal pattern for hailstorms, rain in inches

FIGURE 2. Hail and Rainfall Patterns on 12 March 1967.

The eastward progression of the storms and the size of areas of hailfall for 5-minute periods are shown in Fig. 2b. Their equivalent orientations and expanding hailfall areas in their early stages are clearly shown. One area northeast of West Frankfort experienced hail from both storms (Fig. 2a), and comparison of the times of the hailfall areas (Fig. 2b) in this overlap region shows that these hailfalls were separated by 4 to 10 minutes. The hailfall areas had expanded continuously into their mid-late stages (1650-54 CST for streak 1, and 1655-59 for streak 2), but thereafter the hailfall areas began to decrease, with a rapid diminishment in the final 2 to 3 minutes of their existence.

The isohyetal pattern based on the rainfall produced by the two hail-producing storms is shown in Fig. 2c. Amounts in the area of hailstreak number 1 were not large, generally less than 0.2 inch. The recording raingages were adapted (with funnels removed) to record hailfall "spikes" and thus the amount of water from the hail. Chart records at gages F and V (Fig. 2c) both indicated that most of their total amounts, 0.10 and 0.06 inch, respectively, were from the hail. The storm producing hailstreak number 2 yielded considerably more precipitation than the first storm. Rainfall was increasing, totaling 0.48 inch at gage H (Fig. 2c), near where the hail produced by this storm was terminating.

The surface rainfall and hailfall data furnished several interesting facts concerning these storms. The storm that produced hailstreak number 2 developed along the right-front flank of the storm that produced hailstreak 1, and this conforms to the multi-celled storm model described by Fankhauser and Newton (1965). The detailed study of the rain cores and hail areas at various times during both storms revealed that the larger hail fell in the center of its associated rain core, and not along the right flank as has been postulated for many hailstorm models. Much of the precipitation produced by these spring hailstorms was from the hail. In storm number 1, the hail fell throughout most of the storm's life history, as defined by the period of rain production, whereas the hail from the second storm fell only during the formative stage. However, the hailstreaks were alike in their times of occurrence and durations, areal extents, speeds, production of large hailstones, and their positioning at any given time with respect to their rainfall cores.

Of considerable importance is the fact that many of these findings prove that detailed, careful ground studies of hailstorms are needed to provide information adequate to describe and understand the actual processes involved. For instance, the proximity of the two hailstreaks in these two storms (Fig. 2a) could easily have led to the conclusion that only one large hailstorm had occurred, as outlined in Fig. 1, if detailed time data from many points had not been collected.

Comparison of Storm Damages

The Tri-state tornado covered 28 miles in a 1-mile-wide path across the area of the now existing raingage network. The times at which it

struck certain communities are depicted in Fig. 1. The town of Parrish was 90 percent destroyed (Changnon and Semonin, 1966). In its path across this network area, the tornado killed 188 persons (31% of the Illinois total), injured 492 (32% of the total), and produced $3.1 million (1964 dollars) in damages (9% of the total). The two hailstorms on 12 March 1967 certainly did not approximate this degree of damage, but they did result in more than $100,000 in property losses. Crop losses were minor because the storms occurred before the major crops had been planted. All homes in Orient (Fig. 2a) experienced damage from the combination of high winds and 3-inch stones. The northwestern portion of West Frankfort, which had been devastated by the 1925 tornado, was also that city's prime hail damage area in 1967. Certainly the areas affected by the 1925 and 1967 storms did overlap to a considerable degree. The Tri-state tornado was certainly a "design" event for tornadoes, and the occurrence of 3-inch hailstones is also infrequent. Point frequencies for hailstone sizes in Illinois indicate that 3-inch stones can be expected only once every 20 years (Changnon, 1967). Thus, by chance, two rather rare meteorological events have occurred in the same area.

Recall of Severe Weather Events

After many years of visiting friends and relatives in West Frankfort (Fig. 1) and meeting many persons in that immediate area during the installation of a raingage network in 1957, I became aware of an inordinate fear of thunderstorms among many of the older residents. In particular, older women would call with alarm for the gathering of the family in the storm shelter or basement at the first sight of any dark cloud, regardless of whether any severe storm warnings had been issued. Initially, I attributed this to native fear of the unknown. However, after a careful study of the Tri-state tornado and in subsequent discussions of this event with those who had experienced the storm, it was obvious that their unusual fears were rooted in their experiences during the 18 March 1925 tornado.

The newspaper headline and story reproduced in Fig. 3 came from the 13 March 1967 issue of the *West Frankfort Daily American*. It reveals the local recognition of the coincidence between the two severe storm events, even indicating that the 1967 hailstorms came within 6 days of the forty-second anniversary of the tornado. Interestingly, March 12 and 18 both are in periods with quite frequent occurrences (singularities) of severe weather in Illinois (Changnon, 1962).

The persisting recollection of a single severe weather event in a region by many of those who experienced it is an interesting phenomenon. Ludlum (1968) has reported on such regional persistence in relation to persons experiencing certain very severe midwestern winters in the 1821-1870 period. However, this was in a period when severe weather events 1) exerted more direct hardships on life and property than they generally do today, and 2) were less understood than they

It's Not a Cotton Patch

Large-sized hailstones, ranging from marbles to A-size hen eggs and even some "baseball-sized" pelted the West Frankfort community Sunday evening causing heavy damage to roofs, car tops and aluminum awnings.

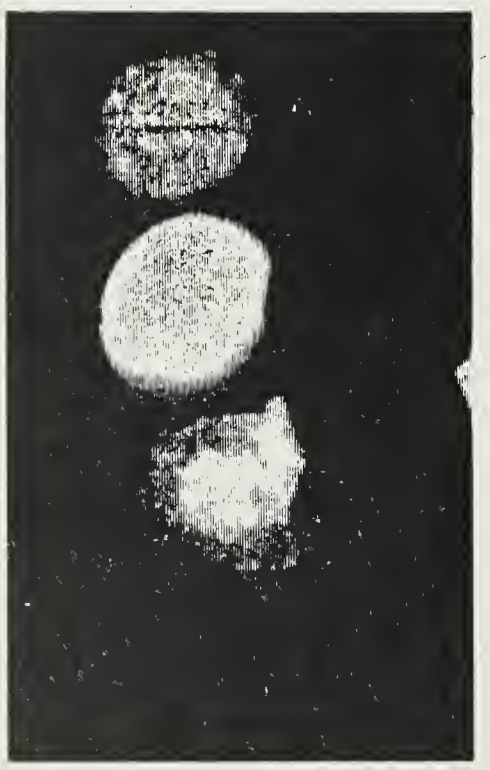
Shades of March 18, 1925 — Huge Hail Stones Pelt Area

MONDAY PAPER

Shades of March 18, 1925.

A big wind, roaring like freight trains, blew over the West Frankfort community area shortly after 5 p.m., Sunday, preceding a pelting by gigantic hail stones that did uncounted damage.

Would You Believe?



That's a Grade A Large chicken egg in the middle. The other two objects are samples of the egg-sized hail that pelted the west side of West Frankfort Sunday evening. "Baseball-sized" hail was reported further west — in the Orient, Plumfield, Zeigler area.

Hail stones were reported ranging in size all the way from mothballs to hen eggs (Grade A Large) to "baseball" size.

The Sunday storm was within a week of matching the date of the 1925 tornado that ripped Southern Illinois and West Frankfort and killed 689 persons in Missouri, Illinois and Indiana.

Late Sunday afternoon, following a balmy unseasonable summerlike day that had the temperature climbing up and nudging the 80 degree mark, billowing decked storm clouds built up the the southwest and west, rolling towards West Frankfort.

Several persons, including this reporter, reported hearing a terrific roaring sound — like several freight trains passing through at high speed — at high altitude preceding the storm of pelting gigantic hail stones.

The hail started slowly at first and then built up in intensity and size until it appeared like it was raining hailstones. They bombarded roofs of houses and garages with such force and intensity that it sounded like a gigantic rock-throwing fight.

When the hail-storm ended it was followed by rain. The ground cover of hail stones slowly disappeared under the melting effect of the rain.

Many Damage Reports

Insurance agencies in West Frankfort today reported receiving numerous damage reports, mostly to roofs, and more were being received through the morning hours.

This reporter saw a convertible auto roof Sunday night that looked like it had been riddled with a shotgun.

Aluminum awnings were bent and dented, as were the roofs of cars and trunk and motor deck lids. Glass panes in green houses were also riddled.

The northwest side of West Frankfort, the same area wiped out by the 1925 tornado, apparently received heavy damage, according to insurance agency reports.

"Baseball sized" hail was reported west of West Frankfort. Hail damage spread both east and west of the community. Both Orient and Zeigler were reported to have been pounded hard by the hail storm. Damage was said particularly heavy in Orient.

Southern Illinois was included in a wide-spread Arkansas, Missouri Kentucky, Illinois and Indiana tornado alert Sunday afternoon by the weather bureau as a "low" moved down a stationary cold front and centered in the Southern Illinois area.

FIGURE 3. Article on 12 March 1967 Hailstorms from the *West Frankfort Daily American* of 13 March.

are today. It is possible that our present capability to meet the challenge of severe winters may never provide us or our descendants with lifelong memories as they did Americans of the Nineteenth Century, although any severe winter storm that disrupts electrical power may be remembered for a period because of our concurrent dependence on electricity.

Another form of prolonged weather disasters that has some lasting effect on the populace are severe droughts, such as those of the 1930's. Comparable future droughts in agricultural areas will likely leave large imprints on the memory and behavior of those experiencing them. Severe floods from heavy rains and/or rapidly melting snow also may continue to produce certain lasting memories in rural and urban areas. However, our current society with its fluid population, extensive means of mass communication, and constant awareness of many worldwide disasters may not remember local severe weather events over long periods of time.

The situation in the Tri-state tornado area 42 years after its occurrence certainly suggests that occasional, exceptionally severe tornadoes or hurricanes of the future may still cause sufficient sudden destruction and deaths to be imprinted also on the memories of those in the storm area through one or more generations. The effect of such severe weather events to condition human activities might well be the subject of future sociological research.

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Manuscript received, April 9, 1969

ADDITIONS TO THE ILLUSTRATED FLORA OF ILLINOIS. I.

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ABSTRACT. — This is the first report on additions to the Illustrated Flora of Illinois series. Four taxa of ferns and fern allies are reported new for Illinois. These are *Equisetum pratense*, *Dryopteris* X *neo-wherryi*. *Woodwardia areolata*, and *Onoclea sensibilis* f. *obtusilobata*. One hundred seventeen additional county records are reported.

This is the first in a series of proposed periodic reports designed to bring up-to-date the Illustrated Flora of Illinois publications. Except where otherwise indicated, the reported records are all based on material examined by the author. Some of the records will represent recently collected material, others will represent herbarium material not previously examined by the author.

Previously unlisted taxa in the Illustrated Flora of Illinois will be included in these reports in the style of the Illustrated Flora. Collection data for new localities of the very rare species will be recorded. Nomenclatural changes, new synonymy, and other nomenclatural matters will be discussed in these periodic reports.

It is hoped that records not included in the Illustrated Flora or in its annual additions will be brought to the attention of the author.

Bibliographical data pertinent to the Illustrated Flora will be appended to each periodic report.

The only volume published to date is concerned with ferns (Mohlenbrock, 1967). Ferns of Illinois was published in April, 1967. Following are the additions since that time to this work. Special gratitude is given to all curators of Illinois herbaria who have graciously permitted periodic study of their collections. Illustrations in this paper have been prepared by Miriam Wysong Meyer.

NEW TAXA

EQUISETUM PRATENSE Ehrh. Hannov. Mag. 22:138. 1784. Fig. 1.

Stems annual, of two kinds; fertile stems whitish or pinkish, appearing in early spring, to 30 cm tall, the sheaths pale, with slender white-margined brown teeth to 15 mm long; fertile stems often bearing spreading, green, whorled, 3-angled branches up to 15 cm long, with the teeth of the sheaths deltoid; sterile stems erect, stiff, whitish-green, appearing in late spring, to 60 cm tall, with 8-20 ridges each with 3 rows of minute spines, with the central cavity about one-sixth the diameter of the stem, the sheaths with teeth up to 8 mm long; cone to 2 cm long.

Common Name: Meadow Horsetail.

Habitat: North-facing wooded slope.

Range: Newfoundland to Alaska, south to British Columbia, north-

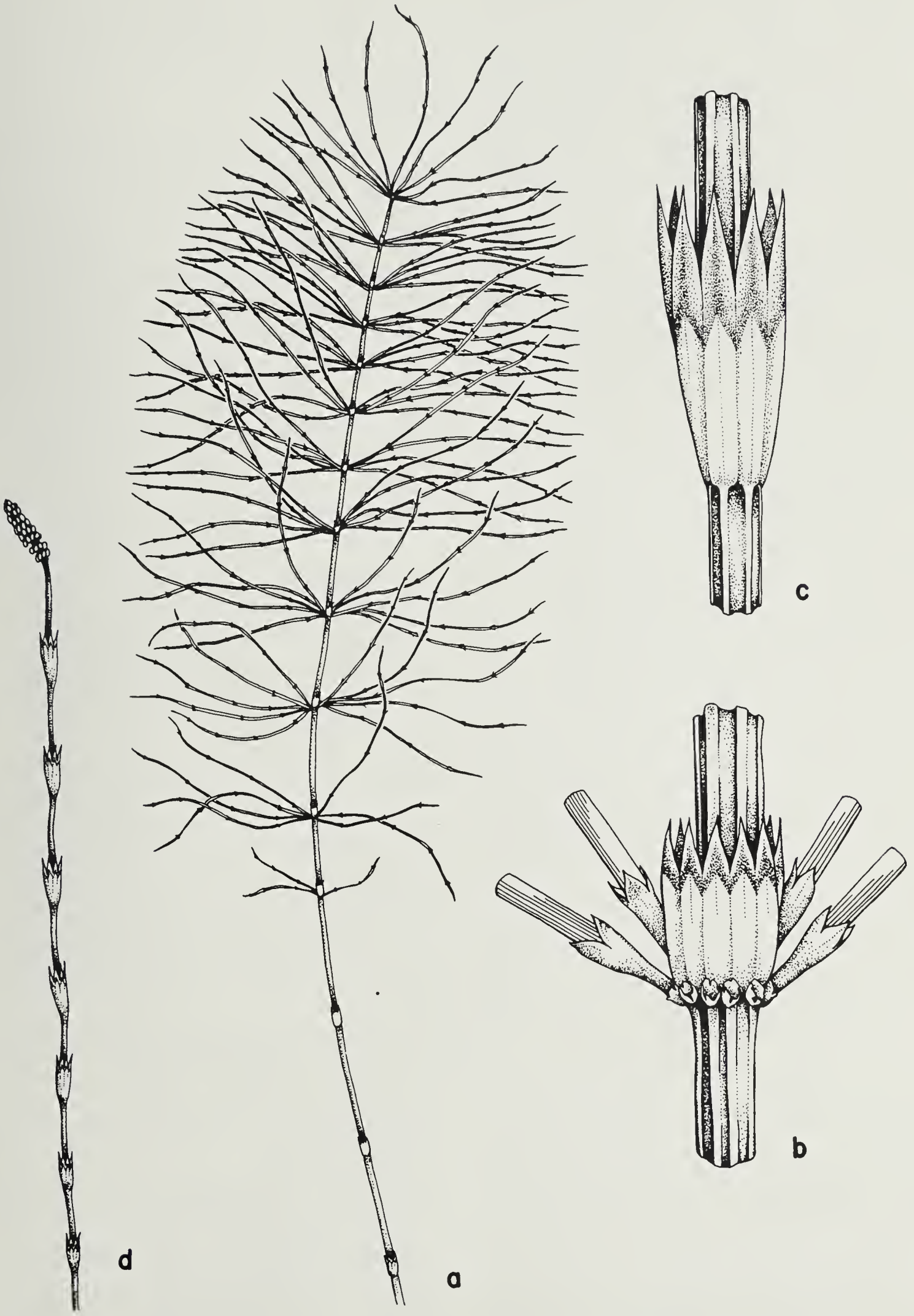

FIGURE 1. *Equisetum pratense.* a. Portion of vegetative branch; b. Portion of reproductive branch; c. Sheath; d. Node with lateral branches.

western Illinois, and New York; Europe; Asia.

Illinois Distribution: Known only from JoDaviess County (Hanover Township, section 20, Mississippi River bluff, *T. Hartley 6340, 6509* (in herbarium of the University of Iowa)).

This species and *E. arvense* are the only species of *Equisetum* in Illinois in which the sterile and fertile stems are dissimilar. *Equisetum pratense* is distinguished from *E. arvense* by the white-margined teeth of the sheaths, the spinulose ridges of the stem, and the short, deltoid teeth of the sheaths of the branches.

This species was first found in Illinois by Thomas G. Hartley during research on the Driftless Areas of Illinois, Iowa, and Wisconsin. Associated with *E. pratense* on the same wooded slope were such unusual species in northwestern Illinois as *Lysimachia quadrifolia, Corallorhiza odontorhiza, Goodyera pubescens, Habenaria viridis* var. *bracteata, Dryopteris cristata, Dodecatheon radicatum, Viola incognita,* and *Orchis spectabilis.*

ONOCLEA SENSIBILIS L. f. OBTUSILOBATA (Schkuhr) Gilb. List N. Am. Pterid. 18. 1901. Fig. 2.
Onoclea obtusilobata Schkuhr, Krypt. Gew. 1:95. 1809.

This form differs from f. *sensibilis* by the flattened, sterile condition of many of the usually fertile pinnules.

This form occurs in very low numbers along with many specimens of f. *sensibilis* at the single Illinois station.

Illinois Distribution: Pope Co.: spring marsh, two miles west of Bay City, *W. Hopkins & R. Mohlenbrock* (S.I.U.). *s.n.*

DRYOPTERIS X NEO-WHERRYI W.H. Wagner in Wagner & Wagner, Castanea 31(2):136. 1966. Fig. 3.

Rhizome short-creeping; leaves more or less evergreen, pinnate-pinnatifid to nearly bipinnate, to 30 cm long, not dimorphic, with 25-35 pairs of pinnae, the pinnae eglandular, with the ultimate segments shallowly toothed; petiole to 15 cm long, scaly at least near base; sori round, borne on the back of the leaf segment midway between the midvein and the margin; indusium eglandular; 82 unpaired chromosomes (Wagner & Wagner, 1966).

Habitat: Rich, rocky woods.

Range: New England to Michigan, south to southwestern Virginia and southern Illinois.

Illinois Distribution: Pope Co.: along Lusk Creek, SW¼, Section 21, T12S, R6E, October 13, 1967, *J. Schwegman 1490.*

This recently described taxon, named in honor of Professor Edgar F. Wherry of the University of Pennsylvania, is a hybrid between *D. marginalis* and *D. goldiana,* and is morphologically intermediate between the two. It occurs in Illinois in close proximity to the two parent species.

WOODWARDIA AREOLATA (L.) Moore, Ind. Fil. 45. 1857. Fig. 4.
Acrostichum areolatum L. Sp. Pl. 1069. 1753.
Lorinseria areolata (L.) Presl, Epim. Bot. 72. 1851.

Perennial from slender rhizomes; leaves dimorphic; sterile leaves pinnatifid, to 25 cm long, over half as broad, firmly membranaceous, the lanceolate divisions minutely

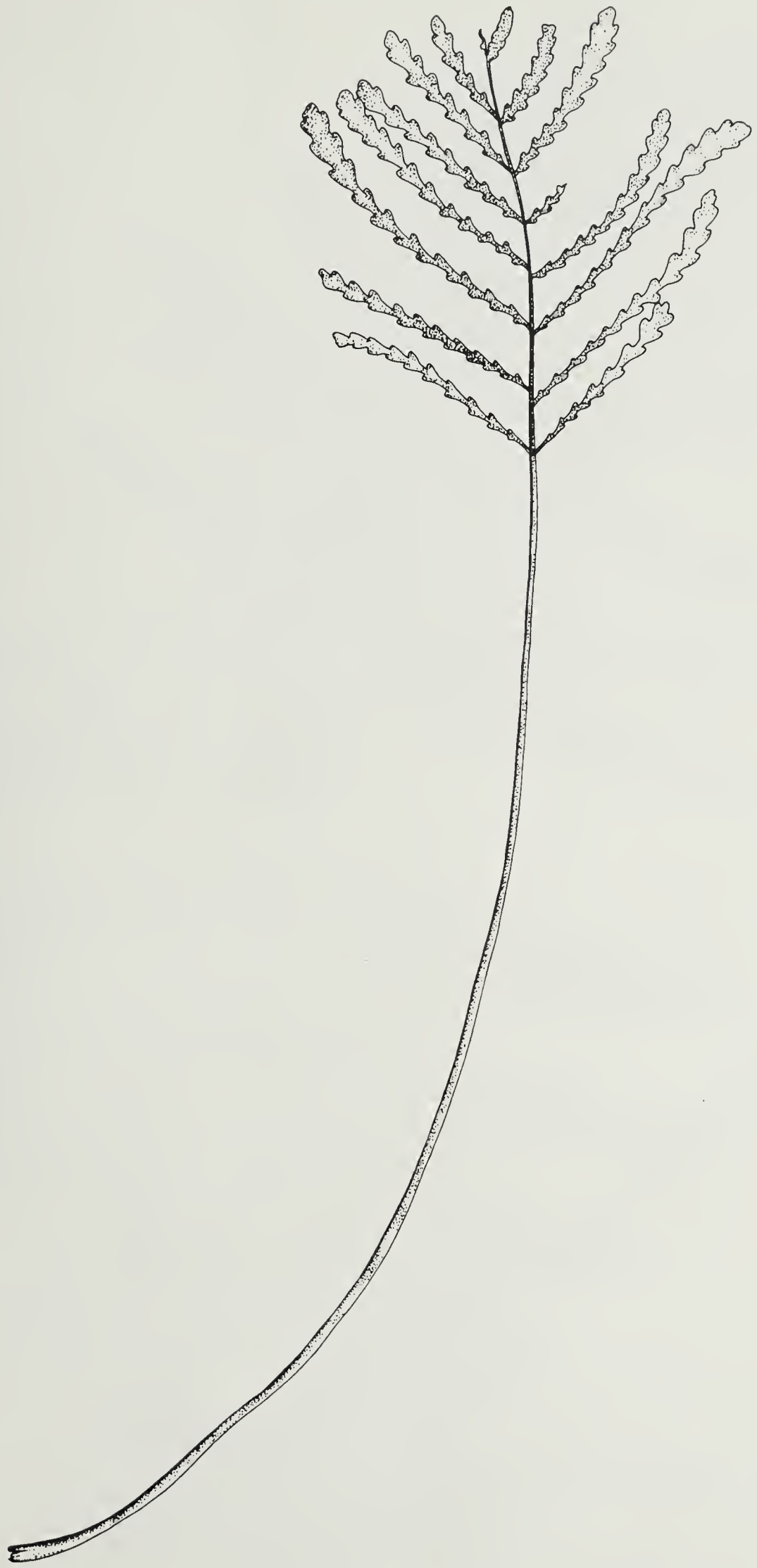

FIGURE 2. *Onoclea sensibilis f. obtusilobata.*

FIGURE 3. *Dryopteris X neo-wherryi.*

FIGURE 4. *Woodwardia areolata.*

toothed, the venation forming several rows of areoles; fertile leaves pinnatifid, to 35 cm long, less than half as broad, the linear divisions cleft nearly to the rachis, bearing areoles and sori in a single row on either side of the secondary midvein; sori elongated, to 10 mm long, the indusium attached to a veinlet on the side away from the midvein.

Common Name: Netted Chain Fern.

Habitat: Springy marsh in lowland woods; edge of sandstone cliff.

Range: Nova Scotia to New Hampshire, south and west to Missouri, Texas, and Florida; Michigan.

Illinois Distribution: Known from two stations in extreme southern Illinois (Johnson and Pope counties).

The first discovery of this fern in Illinois was made by Mr. John Schwegman from a springy marsh in a lowland woods near Massac Tower in Pope County (January 7, 1967, *J. Schwegman 1089*; June 17, 1967, *J. Schwegman 1250*). During August, 1967, it was found along a sandstone ledge at Benson Bluff in Johnson County by R. A. Evers and J. Snider.

Some persons are of the opinion that this species should be segregated into the genus *Lorinseria*. It would seem to me, however, that the best treatment is to consider *W. areolata* and *W. virginica* as members of the same genus, falling into Sections Lorinseria and Anchistea, respectively.

Woodwardia areolata differs from *W. virginica* by its strongly dimorphic leaves with several rows of areoles. In the vegetative condition, *W. areolata* is very similar to the sensitive fern (*Onoclea sensibilis*), but differs in its minutely toothed sterile leaf divisions.

New Records of Previously Reported Taxa

Lycopodium lucidulum Michx. var. *lucidulum*. Cumberland, Johnson.

Selaginella apoda (L.) Fern. Williamson.

Selaginella rupestris (L.) Spring. Union, Winnebago.

Isoetes melanopoda Gay & Dur. Cass, Mason, Pike.

Isoetes butleri Engelm. Gallatin.

Equisetum variegatum Schleich. in Usteri. Coles, DeWitt.

Equisetum X *trachyodon* A. Br. Mason: SE¼, SE¼, SE¼, Section 8, Allen Grove Township, mound of sandy loam, September 12, 1966, *S. L. Wunderle s.n.*

Equisetum laevigatum A. Br. Mercer.

Equisetum X *ferrissii* Clute. Adams, Boone, Champaign, Iroquois, Knox, McHenry, McLean, Menard, Sangamon.

Botrychium multifidum (Gmel.) Rupr. ssp. *silaifolium* (Presl) Clausen. Will.

Botrychium dissectum Spreng. var. *dissectum*. Cass, Coles, Mason.

Botrychium dissectum Spreng. var. *obliquum* (Muhl.) Clute. Cass, Edgar, Jersey, Mason, Morgan, Schuyler, Scott, Whiteside.

Ophioglossum vulgatum L. Coles.

Ophioglossum engelmannii Prantl. Johnson, Pope.

Osmunda cinnamomea L. Madison, Winnebago.

Osmunda claytoniana L. Coles, Cumberland, Madison, Pike.

Dennstaedtia punctilobula (Michx.) Moore. Johnson: north-facing sandstone cliffs, Ferne Cliff State Park, October 30, 1968, *J. Schwegman 2093*.

Pteridium aquilinum (L.) Kuhn var. *latiusculum* (Desv.) Underw. ex Heller. Cass, Logan, Mason, Menard, Tazewell.

Pellaea atropurpurea (L.) Link. Calhoun, JoDaviess, Massac, Scott.

Pellaea glabella Mett. ex Kuhn var. *glabella*. Greene, St. Clair.

Cheilanthes feei Moore. Scott.

Cheilanthes lanosa D. C. Eaton in Torr. Cumberland, Massac, Ogle.

Polypodium polypodioides (L.) Watt var. *michauxianum* Weatherby. Calhoun, Massac.

Onoclea sensibilis L. McLean.
Matteuccia struthiopteris (L.) Todaro. Adams.
Thelypteris hexagonoptera (Michx.) Weatherby. Cumberland, Greene, Scott, Shelby, White.
Thelypteris noveboracensis (L.) Nieuwland. Pope.
Dryopteris carthusiana (Villars) H. P. Fuchs. Cumberland, DeKalb, Schuyler, Stephenson.
Dryopteris cristata (L.) Gray. JoDaviess, Pope.
Dryopteris goldiana (Hook.) Gray. Pope.
Dryopteris intermedia (Muhl.) Gray. Fulton, Gallatin.
Dryopteris marginalis (L.) Gray. Cumberland, Madison, McLean, St. Clair.
Athyrium pycnocarpon (Spreng.) Tidestrom. Cass, Cumberland, Schuyler.
Athyrium thelypterioides (Michx.) Desv. Coles, Cumberland, Jersey, Madison, Pike.
Athyrium filix-femina (L.) Roth in Roem. var. *rubellum* Gilb. Brown, Bureau, Coles, Cumberland, Lee, Whiteside.
Athyrium filix-femina (L.) Roth in Roem. var. *asplenioides* (Michx.) Farw. Johnson, Pope, Union.
Asplenium rhizophyllum L. Coles.
Asplenium pinnatifidum Nutt. Cumberland, Fulton, Massac.
Asplenium trichomanes L. Cumberland, Massac.
Asplenium platyneuron (L.) Oakes ex D. C. Eaton. JoDaviess, Scott.
Cystopteris bulbifera (L.) Bernh. Hardin.
Woodsia obtusa (Torr.) Spreng. Cumberland, Warren.
Marsilea quadrifolia L. Coles.
Azolla mexicana Presl. Franklin, Johnson, Monroe, Morgan, Scott.

Additional Synonymy

The following additional synonyms should be inserted as indicated:

Under *Dryopteris marginalis* (L.) Gray:

Nephrodium marginale f. *davenportii* Floyd, Rhodora 4:245. 1902.
Dryopteris marginalis f. *davenportii* (Floyd) A. R. Prince ex Weatherby, Am. Fern Journ. 26:62. 1936.

This and all other crested forms listed here are thought by me to be unworthy of nomenclatural splitting. Therefore, I am relegating each to synonymy under the proper species. The crested form of *Dryopteris marginalis* has been found in Pope County (Mohlenbrock & Wunderle, 1967).

Under *Polystichum acrostichoides* (Michx.) Schott:

Polystichum acrostichoides f. *cristatum* Clute, Fern Bull. 20:81. 1912.

This is the crested form of Christmas Fern, known from Union and Cumberland counties (Mohlenbrock & Wunderle, 1967; Wunderle, 1968).

Under *Polystichum acrostichoides* (Michx.) Schott:

Polystichum acrostichoides f. *crispum* Clute, Our Ferns in Their Haunts 107. 1901.

This form has pinnae with wavy margins. It is reported by Wunderle (1968) from Cumberland County.

Under *Polystichum acrostichoides* (Michx.) Schott:

Polystichum acrostichoides f. *multifidum* Clute, Fern Bull. 15:71. 1907.

This form of Christmas Fern has deeply pinnatifid pinnae. It is reported by Wunderle (1968) from Cumberland County.

Under *Thelypteris hexagonoptera* (Michx.) Weatherby:

Dryopteris hexagonoptera f. *simonii* Reed, Am. Fern Journ. 35:105. 1945.
Thelypteris hexagonoptera f. *simonii* (Reed) Wunderle, Trans. Ill. Acad. Sci. 61:321. 1968.

This is a crested form in which the pinnatifid pinnae fork. It is reported by Wunderle (1968) from Cumberland County.

Under *Cystopteris fragilis* (L.) Bernh. var. *protrusa* Weatherby:

Cystopteris fragilis var. *cristata* Lowe, Out Nat. Ferns 2:432. 1869.
Cystopteris fragilis f. *cristata* (Lowe) Weatherby, Am. Fern Journ. 26:13. 1936.

The crested form is reported from Cumberland County by Wunderle (1968).

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THE INFLUENCE OF THE HOMEOTIC MUTATION, "ANTENNAPEDIA", ON EGG CANNIBALISM IN *TRIBOLIUM CASTANEUM*

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ABSTRACT. — A comparison of egg cannibalism by adults of differing genotypes (normal wild type versus the homeotic mutation, antennapedia) in the flour beetle, *Tribolium castaneum*, was performed. Egg cannibalism over a 24-hour period was examined for adult density levels of one, two, four, eight, sixteen and thirty-two pairs. A significant reduction in egg cannibalism was observed for beetles homozygous for antennapedia from that of homozygous wild-type at all levels. The effects of antennal ablation were also examined for both genotypes and found not to exhibit a significant influence upon the total results observed.

Much work has been conducted on egg cannibalism in the flour beetles of the genus, *Tribolium,* however, the approach has been primarily from the standpoint of its influence upon population growth and regulation. An extensive review of this ecological approach and detailed references are found in Park *et al.* (1965).

However, the possible effects of different genetic influences upon such an important regulatory mechanism were not examined in previous studies. One approach to this question is an assessment of the influence of a single gene upon egg cannibalism. It is the purpose of this study to report such an influence upon egg cannibalism as affected by the homeotic mutation, antennapedia, *ap* (Englert and Bell, 1963a) in the red rust flour beetle, *Tribolium castaneum.*

MATERIALS AND METHODS

The genetic material tested was derived from a mass mated non-inbred population known as the Purdue "+" Foundation stock and a stock homozygous for the mutation "antennapedia," *ap.*

To insure that intrinsic factors such as age, viability, and fecundity rate were controlled as much as possible, the beetles used were collected as pupae and kept as mated pairs until 21 days after emerging as adults.

At this time they were introduced at their selected density levels to 20 ml glass creamers containing 5 gm standard culturing medium (95% whole wheat flour and 5% dried brewer's yeast). Homogeneously distributed throughout the

medium were 100 eggs which had been marked by using a neutral red dye in a manner similar to that used by Rich (1956). The culture creamers had been acclimated for ten days prior to introduction of adult beetles and marked eggs. The investigation was conducted in a Labline Incubator, Model R-1130, which provided constant environmental conditions for temperature and humidity at 33 ± 3°C and 65 ± 5%, respectively.

Density levels which were chosen for this study were one, two, four, eight, sixteen, and thirty-two adult pairs per 5 gm culturing medium.

At the end of 24 hours, both adults and eggs were removed, and all marked and unmarked eggs recovered were counted to determine the rate of cannibalism occurring. Cannibalism rate was calculated using the basic generalized formula of Rich (1956), later modified by Sonlietner (1961):

$$c = (1/bt) \log_e (M_o/M_t)$$

where c = the cannibalism rate; b = number of beetles; t = time in days; M_o = number of marked eggs introduced; and M_t = number of marked eggs recovered.

Results

The cannibalism rates presented in Table 1 clearly indicate that for all density levels the rate exhibited by the *ap* genotype is significantly reduced from that of the normal wild-type genotype. It is also evident, that as the number of adults increased, the rate of cannibalism decreased for both genotypes. However, the decline in cannibalism rate does not behave in a similar manner over densities for the two genotypes.

Table 1. Cannibalism rates (mean ± standard error)† of antennapedia and normal wild-type adult beetles at varying densities.

Number of Pairs	Genotype		Number of Replicates
	+/+	*ap/ap*	
1.....	6.62 ± 0.62	5.24 ± 0.64	10
2.....	5.27 ± 0.39	3.50 ± 0.44	10
4.....	4.57 ± 0.23	2.15 ± 0.02	5
8.....	3.19 ± 0.02	2.78 ± 0.04	5
16.....	4.55 ± 0.02	2.76 ± 0.16	5
32.....	3.16 ± 0.02	2.20 ± 0.01	5

† c X 10^2

An analysis of variance (Table 2) was performed on the data to determine whether the differences observed were of statistical significance. Since ten replicates were employed at the one and two pair density levels, thus presenting unequal subclass numbers, the analysis was performed using unweighted means and correcting the error term with the harmonic mean (Snedecor and Cochran, 1968). The main effects, genotype and density, were shown to be statistically significant, as suggested by the magnitude of the standard errors presented in Table 1.

Of equal interest is the GxD interaction term, which also reveals statistical significance, verifying our earlier suggestion that the two genotypes reacted in a different manner with regards to egg cannibalism at differing density levels. While the general pattern of decline for the two genotypes differs specifically at the eight and sixteen pair density levels, both do exhibit an interruption in the decline of cannibalism rate at these levels, suggesting possibly that this may be a critical level of adult density versus egg number for population control regardless of genotype.

TABLE 2. Analysis of variance for egg cannibalism.

Source of Variation	d.f.	Mean Square
Genotype (G)	1	43.02**
Density (D)	5	17.70**
G x D	5	7.23**
Error (corrected)	68	0.87

** $P < .01$

In an attempt to learn whether the morphological effects of this homeotic mutation was that of reducing the searching ability of the beetle through a modification of its antenna, a supplementary experiment involving antennal ablation was conducted. Choosing a density level where the differences between the two genotypes were the greatest (four pairs), wild-type beetles were examined for differences in cannibalism rate for intact antennae, removal of left antenna only, and both antennae removed. Antennapedia beetles were compared only for differences between intact antennae and both antennae removed. The

results of this test are given in Table 3.

There appears to be a slight difference between the intact and the non-intact antennae for the wild-type genotype, but not for antennapedia. However, when an analysis of variance was performed, significance was observed only for genotypes and not for treatment or the treatment by genotype interaction (Table 4). Therefore, we can say that antennal ablation had no effect upon cannibalism rate, since the mutant maintained its basic difference under both treatments.

Discussion

While the results presented here were obtained under controlled and optimum conditions: unconditioned medium, 24-hour time restriction, optimum age of adults for high fecundity, and optimum temperature and humidity conditions, the difference noted between the two genotypes for cannibalism rate is considered real.

The entire question of egg cannibalism by adults regardless of genotype is based upon a number of assumptions being met. These in-

Table 3. Cannibalism rates (mean ± standard error)† following ablation of both normal wild-type and mutant antennae at a density of four pairs.

Antennal Ablation	Genotype		Number of Replicates
	+/+	*ap/ap*	
Intact	4.57 ± 0.28	2.15 ± 0.26	5
Both removed	3.50 ± 0.63	2.29 ± 0.50	5
Left antenna only	2.72 ± 1.10	.....	5

† c X 10^2

Table 4. Analysis of variance for egg cannibalism following antennal ablation.

Source of Variation	d.f.	Mean Square
Genotype (G)	1	11.39**
Treatment (T)	2	0.87
G x T	1	6.96
Error	20	1.37

** $P < .01$

clude: (1) no non-random searching for eggs exists, (2) adult beetles exhibit no appetite "satiation", and (3) marked and unmarked eggs are equally likely to be cannibalized.

To minimize any major deviations from the first assumption the time of adult exposure was limited to the 24-hour period, thus providing a common base for comparison between genotypes. Sonleitner (1961) has demonstrated for *T. castaneum* that the latter two assumptions do hold, therefore, no attempts have been made here to minimize these effects, other than keeping the number of eggs constant (100) for each density level.

The increase in adult density without a corresponding increase in egg density did, however, most likely contribute to the decline in cannibalism rate observed for both genotypes. Rich (1956) has demonstrated a positive correlation of egg cannibalism rate with egg density.

By restricting the number of eggs available to the adults, those adults at the lower densities actually have available more eggs per beetle than do the adults of the higher densities. It appears that the behavior of the two genotypes differ in the exact density level at which the decline is stabilized.

It might be argued that the difference in cannibalism observed for the two genotypes may actually then be a difference in fecundity rate, and thus the difference observed is purely a function of total number of eggs available, particularly to the wild-type beetles. However, Englert and Bell (1963b) have shown that the fecundity of the antennapedia mutation is as high as its normal wild-type counterpart, thus this factor cannot explain the differences observed.

An attempt to examine the role of the antenna *per se* in egg cannibalism has revealed no significant difference in the cannibalism rate at a density level of four pairs of adults for either genotype when the antennae are intact or removed, although the genotype difference still persisted. Such evidence is indicative of the fact, that although the antennapedia mutation changes the morphological structure of the antenna, its affect on whatever role the antenna may play in egg cannibalism is not similarly affected.

Thus, the cause for a reduction in egg cannibalism by antennapedia adults lies in an area other than antennal structure *per se*. One such cause which was not examined here is behavior of antennapedia in regards to the preference in movement upon the surface of the medium rather than randomly tunneling throughout the medium, thus reducing the number of eggs each adult will encounter.

Another possible cause, again one of behavior, is that the actual response of "egg encounter" is itself specific and non-random, and the egg cannibalism is the result of the encounter only if a "taste" or "satiation" preference exists. An alteration of such a preference for the antennapedia beetles may be an indirect result of the basic action of the gene itself. Such a behavioral change would be difficult indeed to examine.

Egg cannibalism is considered to be of importance in regulating the upper limits of population growth,

in that it plays a major role in reduction of the rate of larval hatching (Sonleitner, 1961). A reduction in such an important regulating mechanism brought about by a single gene mutation would place a population at a distinct disadvantage for self-regulation.

Acknowledgment

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SPATIAL DISTRIBUTION CHARACTERISTICS OF RAINFALL RATES IN ILLINOIS

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ABSTRACT. — A convenient method of describing the spatial distribution of storm rainfall rates for hydrological and meteorological applications is through the construction of area-depth envelope curves. From these, the rainfall rate equalled or exceeded over any fractional part of a sampling area can be determined. This method was used in the analyses of 1-minute rainfall data from 29 warm-season storms on a 50-gage network of 100 mi² in 1952-1953. These storms yielded 3142 area-depth curves of 1-minute rates, which closely approximate the instantaneous storm rainfall distribution on the sampling area. Furthermore, consecutive 1-minute area-depth curves provide both a space and time measure of storm rainfall rate variations in a single family of curves. From these data, first approximations of the frequency distribution of rainfall rates in Illinois warm-season storms were obtained and a typical time-space distribution model of rainfall intensity for such storms was developed.

The distribution of storm rainfall rates has important hydrological and meteorological applications. In hydrology, this knowledge is pertinent in establishing urban storm drainage systems while in meteorology it provides basic cloud physics information. Additionally, adequate climatological knowledge of rainfall rate may provide a useful tool in the evaluation of weather modification experiments or in the design of communication equipment.

The purpose of this study was not to establish climatological means or frequencies in view of the restrictions in sample size and sample randomization; rather, the aim was to provide first approximations which could be used where quantitative information on rainfall rate is needed. Both time and space characteristics were investigated.

DATA USED

In this study, 29 warm-season storms (April-October) were analyzed for 1-minute rainfall amounts. The data were collected in a 50-gage network on 100 mi² in east central Illinois during 1952-1953. The primary criteria for storm selection was the availability of radar data for the date of the storm. These storms yielded 3142 minutes from which the basic analyses were made.

The 1-minute rates were obtained from recording raingages with enlarged orifices and 6-hour charts which allowed reading amounts in 0.001 inch per minute (Huff and Neill, 1957). These gage charts were time synchronized to enable accurate time analysis.

Analysis Procedures

A convenient method of defining the spatial distribution of storm rainfall rates is through the computation of area-depth envelope curves. From these curves, the 1-minute rainfall rate equalled or exceeded over any fractional part of the sampling area can be determined. These rates closely approximate the instantaneous storm rainfall characteristics on the sampling area. Furthermore, consecutive 1-minute area-depth curves provide both a space and time measure of storm rainfall rate variations in a single family of curves.

In a uniformly distributed network of raingages, the area-depth envelope curve is constructed from a ranking of raingage values from high to low. Otherwise, the curve is determined from planimetering of network isohyetal maps.

Area-Depth Relations

First, a frequency distribution of area-depth envelope relations on the 100 mi^2 was determined from the 3142-minute sample. Results are summarized in Fig. 1, in which the rainfall rate equalled or exceeded is related to cumulative percent of the sampling area for various percentages of the minutes making up the sample. Thus, the 5-percent curve shows the rainfall rate equalled or exceeded in the 5 percent of the minutes with the heaviest rainfall rates for any fractional part of the area enveloped in the range from 2 percent to 98 percent of the area. Since this network encompasses 100 mi^2 a range from 2 mi^2 to 98 mi^2 is included. It should be understood that the fractional areas in Fig. 1 are not fixed. That is, the 2 percent of the area with heaviest rates may change in location from minute-to-minute within storms as well as between storms. It specifies the heaviest rates experienced any place on the network in a given minute.

Interpretation of Fig. 1 is illustrated by referring to the 2 percent of the area with heaviest 1-minute rates in the 29 storms. There, it is seen that 5 percent of the 3142 minutes had rates equalling or exceeding 4.6 in/hr. This decreased gradually to 0.36 in/hr in the 50 percent of the minutes with heaviest rates, and to 0.04 in/hr when 95 percent of all minutes were included. Similarly, over 50 percent of the area, 5 percent of the minutes had a rate of 0.5 in/hr or greater, and this decreased to 0.03 in/hr for the upper 50 percent of the minutes, and to less than 0.01 in/hr when 95 percent of the 3142 minutes were included.

Fig. 1 does not include a sufficient number of storms to accept it as a true frequency distribution of rainfall rates. However, as indicated earlier, it does serve as a first approximation of the frequency distribution in warm season storms. Also, it provides quantitative information on the spatial variability of rates within a fixed area of 100 mi^2 and the degree of time variance of rates. For example, the 5 percent curve shows a spatial range from 4.6 to 0.07 in/hr as the area for which the enveloping rainfall rate is determined increases from 2 to 98 mi^2. Similarly, for the 2 percent of area with the heaviest rates in the 3142 minutes, the rate ranges from 4.6 in/hr to 0.04 in/hr between

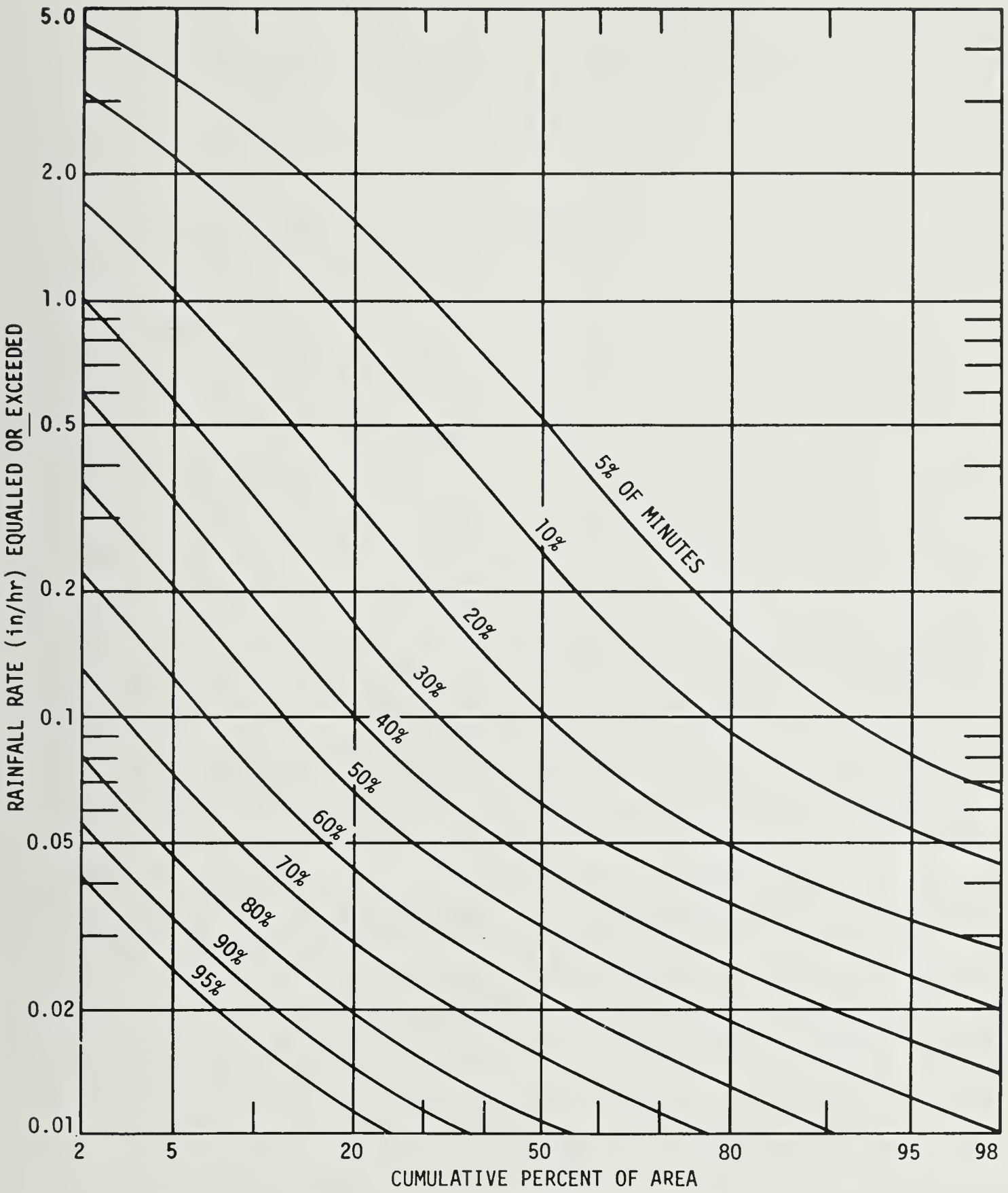


FIGURE 1. Frequency Distribution of Area-Depth Envelope Values.

5 percent and 95 percent of the total minutes.

The 3142-minute sample from 29 storms was used in making other analyses to define further the spatial distribution characteristics of rainfall rate, with particular emphasis on the time variability in the spatial distribution. One result of these analyses is summarized in Fig. 2a (left). This figure shows a family of median area-depth envelope curves on the 100 mi^2 for selected percentages of the storms. The fami-

ly was derived in the following manner. For each storm, area-depth envelope curves of rainfall rate were calculated for each minute during the storm. At selected fractions of the 100 mi^2 area, the 1-minute rainfall rates for the storm were ranked from high to low. The median values from each storm were then used to construct the family of curves in Fig. 2. These curves were found to fit closely an equation of the form:

$$\text{Log } R_e = a + b\ A^{0.5} \qquad (1)$$

where R_e is the enveloping rainfall rate, A is area enclosed, and a and b are regression constants.

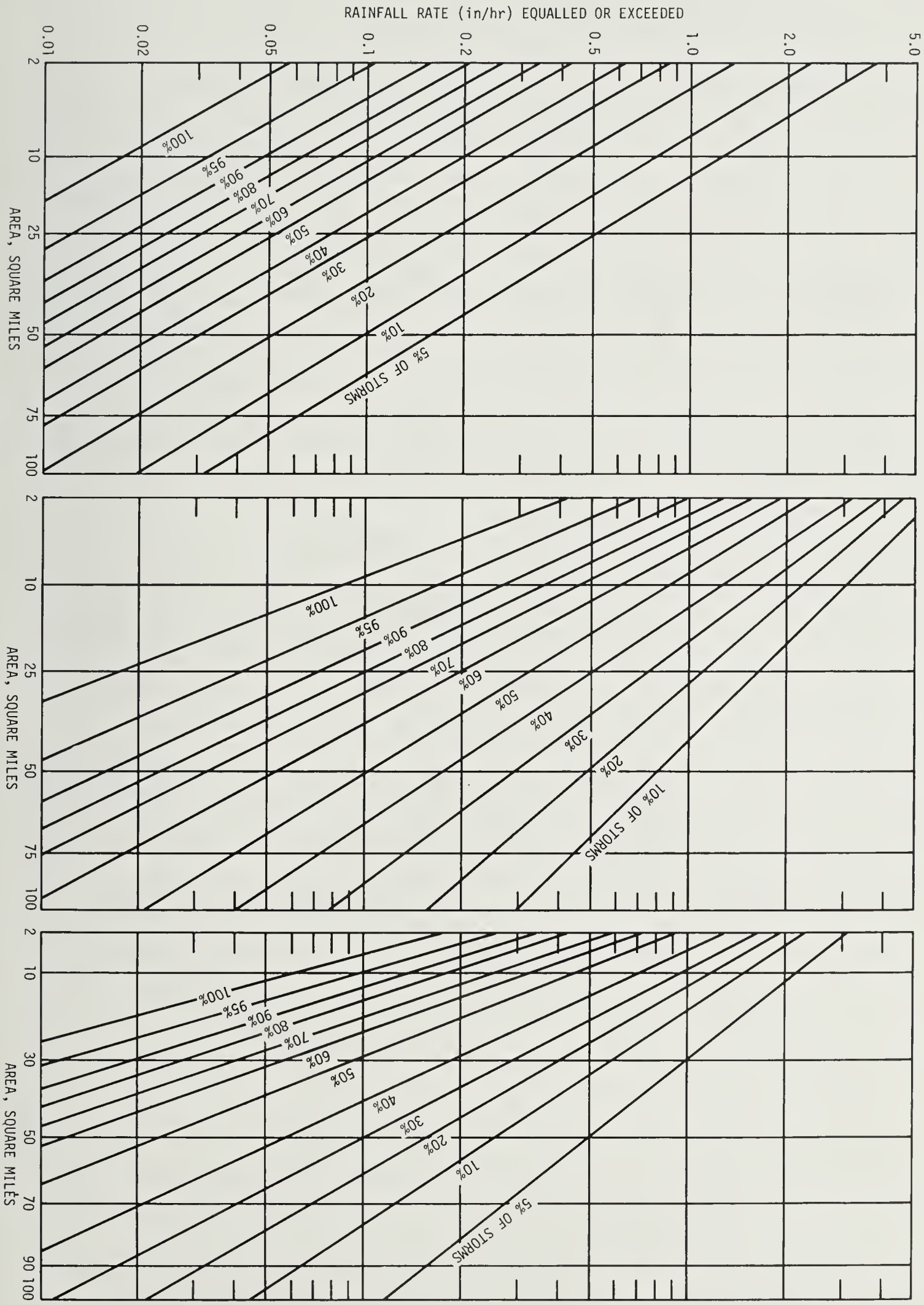
Figure 2a provides a statistical model of typical area-depth curves of 1-minute rainfall rate in warm season storms of various intensity. Thus, the median rainfall rate distribution in the most intense storms in the 29-storm sample is portrayed by the curve for 5 percent of the storms. This curve shows the enveloping rainfall rate ranging from 3.8 in/hr over the 2 mi^2 of heaviest intensity to 0.03 in/hr over the entire 100 mi^2. Similarly, the 50 percent curve shows a range from 0.43 in/hr to less than 0.01 in/hr. These individual percentage curves provide a quantitative measure of the spatial variability in storms of varying intensity.

For some purposes, one may be more interested in extreme rates rather than median or average rainfall rates to be expected in storms. The ranked 1-minute data for each storm can be used also to obtain a measure of the distribution of heavy rates, and this has been done in Fig. 2b (center). Here, the area-depth envelope curves for the 10 percent of the minutes with heaviest rainfall in each storm were used to derive the family of curves. Interpretation of this family is the same as for Fig. 2a. Thus, in 10 percent of the storms sampled the area-depth envelope curve for the 10 percent of the storm with heaviest intensities had enveloping rainfall rates decreasing from 5.8 in/hr at 2 mi^2 to 0.3 in/hr over the entire 100 mi^2. All storms (100%) had rates of 0.42 in/hr or more on 2 mi^2 during the heaviest part of the storm but less than 0.01 in/hr when the entire 100 mi^2 is included. Together, Figs. 2a and 2b provide quantitative estimates of median and extreme rates likely to occur within and between typical warm season storms.

Fig. 2c (right) shows a family of curves similar to those in Fig. 2a. Method of determination was the same, except average rates rather than median rates were employed in development of the Fig. 2c, since some users may be more interested in this statistic. In this case, the family of curves was found to fit an equation of the form:

$$\text{Log } R_e = a + b\ A^{0.8} \qquad (2)$$

Because of the extreme skewness in the distribution of 1-minute rainfall rates in 29 storms, substantial differences exist between the average and median sets of curves. The average curves show higher rainfall rates for a given area and given percent of storms.


RAINFALL RATE (in/hr) EQUALLED OR EXCEEDED
0.01
0.02
0.05
0.1
0.2
0.5
1.0
2.0
5.0
AREA, SQUARE MILES
2
10
25
50
75
100
100%
95%
90%
80%
70%
60%
50%
40%
30%
20%
10%
5% OF STORMS
AREA, SQUARE MILES
2
10
25
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75
100
100%
95%
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80%
70%
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2
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70%
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5% OF STORMS

Fig. 3a (left) shows a median space-time distribution of storm rainfall rates derived from the 29-storm sample. It was obtained in the following manner. For each storm an area-depth envelope curve of rainfall rate was obtained for each minute. Thus, a family of curves similar to Fig. 2a was obtained for each storm. Then, the median curve for each 10 percent of the minutes from the 29 storms was used to construct Fig. 3a. Based on the 29-storm sample, Fig. 3a can be interpreted as a typical space-time distrbution in warm season storms. Fig. 3b (right) provides the same type of information, but is based upon averages rather than medians.

Area-depth envelope relations were developed also for 25- and 50-mi² areas within the 100-mi² network. Characteristics of these envelope curves were similar to those for 100 mi², and, therefore, need no further discussion here.

Summary and Conclusions

This study has provided first approximations of the frequency distribution of rainfall rates in Illinois warm-season storms and permitted development of a typical time-space distribution model of rainfall intensity for such storms. This information should provide useful knowledge for both hydrological and meteorological applications, especially in urban hydrology problems and in weather modification experiments.

Results indicate large rate changes frequently from minute-to-minute because of the steep rainfall gradients, small size, and short life-cycle of convective storm cells. Investigation showed little difference between the distributions over 25 mi² and 100 mi² areas.

Acknowledgment

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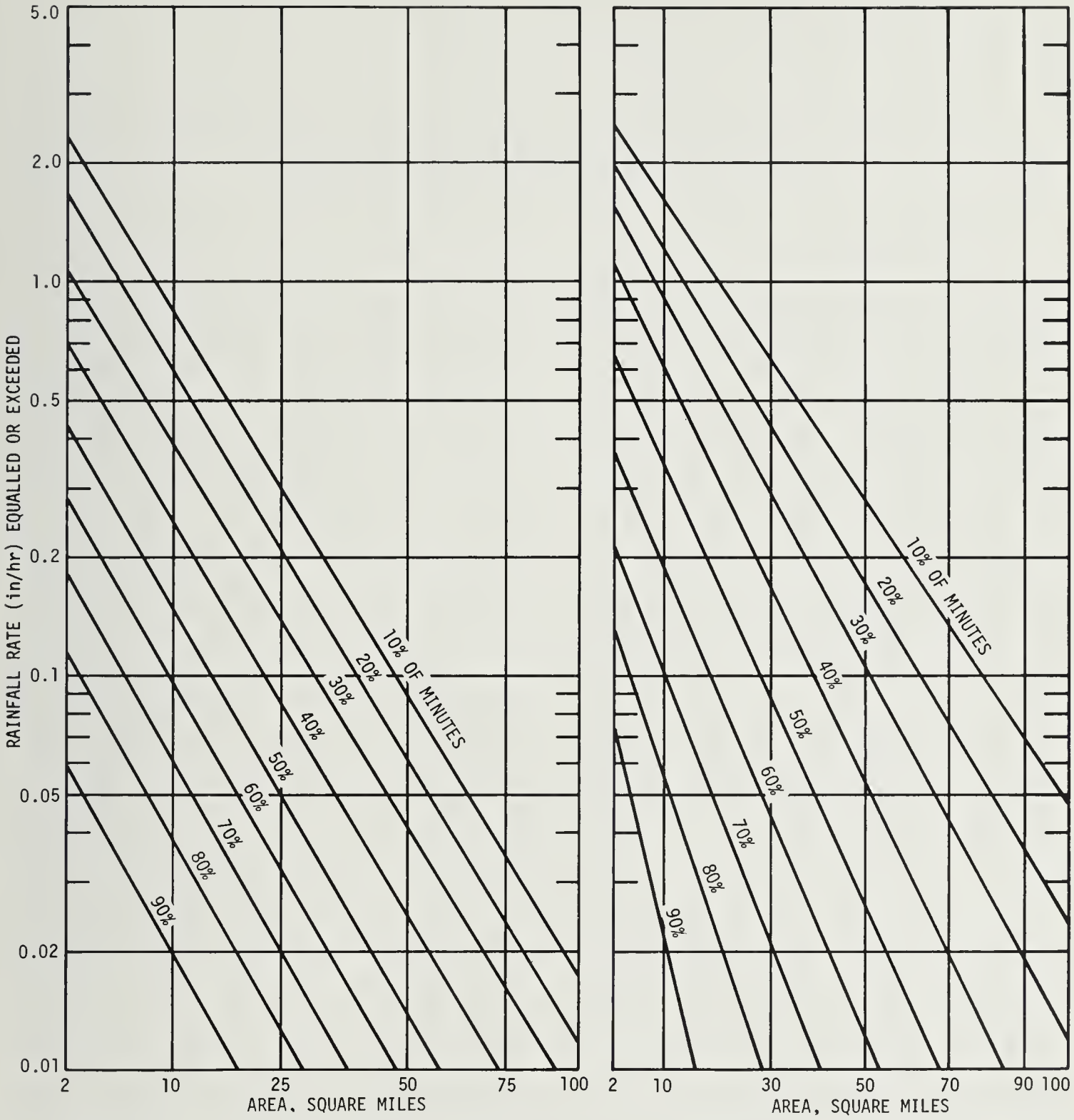

FIGURE 3. **Area-Depth Storm Models Based on Median and Average Values.**

IMMUNOLOGICAL FUNCTION STUDY OF THE BURSA OF FABRICIUS: IMMUNOCOMPETENCE INDUCING AGENT

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ABSTRACT. — The developing bursa of Fabricius and surrounding primordia were removed from 8 day chicken embryos and grown *in vitro*. The nutrient was changed every 24 hours; the collected nutrient was stored under sterile conditions. The organ cultures developed and survived to an equivalent of 4 weeks post-hatching, based on macroscopic observations. The collected nutrient from each culture was filtered to insure absence of bursal cells and intraperitoneally injected into 5 day chicks which had been rendered bursaless by either hormonal suppression or surgical excision.

The immunological capacity of these a-immunologic birds was compared with normally developed individuals by the ring test, demonstrating a restoration of antibody production.

The bursa of Fabricius, a lymphoid organ located dorsally on the cloaca, has been implicated in the production of antibodies in young chickens. Developing in a manner similar to that of the thymus in mammals, bursal primordia appears about day 5 of incubation as an epithelial outgrowth of the cloaca, with a subsequent atrophication after 5 or 6 months and persistance as a fibrous remnant in sexually mature birds (Hamilton, 1952, p. 390-393). Glick *et al.* (1956), demonstrated that surgical removal of the bursa of Fabricius of young chickens prevented the development of normal antibody production. Meyer *et al.* (1959), reported complete inhibition of bursal development by administration of 19-nortestosterone on day 5 of incubation with an accompanying reduction in antibody response. Jankovic and Leskowitz (1965) implanted, in surgically bursectomized birds, bursal material enclosed in a millipore chamber, with a resulting partial restoration of antibody formation. This was substantiated by St. Pierre and Ackerman (1965) in a similar experiment with hormonally inhibited chicks, suggesting that the bursa of Fabricius functions in an endocrine-like manner by the elaboration of a non-cellular agent which diffused across a millipore membrane and was capable of restoring immunologic activity. Nevertheless, Cooper *et al.* (1966), failed to restore antibody production in bursaless chicks by injection of a homogenate of bursal tissue. This led us to believe that a homogenization process did not allow for the accumulated action, of what we term the immunocompetence inducing agent. We thus proposed a collection of such an agent from the *in vitro* growth of the bursa of Fabricius which would more closely approximate *in vivo* conditions. Its presence would then be demonstrated by a subsequent restoration of antibody activity in bursaless birds by injection of the collected agent.

Materials and Methods

Organ culture. The developing bursa of Fabricius and surrounding primordia were surgically removed from 8 day White Leghorn chicken embryos, placed on the grid of a sterile, 60 X 15 ml. BBL organ culture dish and bathed in a sterile nutrient consisting of 100 ml. buffered saline-agar B (Rugh, 1962, pp. 429-430), to which was added 3 vials of lyopholized chick embryo extract (BBL) and 10,000 units each of penicillin and streptomycin. The nutrient was changed every 24 hours, using sterile technique; the "used" or collected nutrient was stored at 37° C in covered flasks reserved for each culture dish. The sterile condition of the collected nutrient was verified by negative tests on nutrient agar plates. The organ cultures were incubated at 37° C and developed to an equivalent of 24-28 days post-hatching, based on macroscopic observation, with detectable differentiation of tissue into a bursa of Fabricius, a cloaca, a spine, etc. 41 days after initiation, the organ cultures were terminated, the collected nutrient was filtered through a Buchner vacuum funnel with large pore filter paper to remove the agar, again filtered through a 0.45 micron millipore filter to remove any intact cells, and then pooled and stored in sealed vials at 37° C for future use.

Experimental animals. Randomly selected White Leghorn chicken eggs (Group A) were injected (Meyer *et al.*, 1959, p. 890) on day 5 of incubation with 19-nortestosterone (CalBioChem) to hormonally suppress bursal development; a second group (Group B) of newly hatched chicks was surgically bursectomized, following the technique of Glick *et al.* (1956, p. 244); while a third group (Group C) was allowed to incubate and hatch normally. 5 days post-hatching, both groups of bursaless chicks were subdivided (Groups A1, A2, B1 and B2) into equal numbers and one subdivision of each group (Group A1 and B1) was injected intra-peritoneally with 3 ml. of the filtered nutrient obtained from the organ cultures, while the other subdivisions (Group A2 and B2) were not injected. 45 days post-hatching, all 5 groups (Group A1, A2, B1, B2 and C) were injected with 200 mg. of crystallized bovine serum albumin (BSA-Pentex); 9 days later all the birds were bled by heart puncture and the serum collected. Using the ring test for precipitate (Kabat and Mayer, 1961, p. 72), the antibody reactivities of the serum samples to BSA were determined.

Results and Discussion

The restoration of antibody activity in the bursaless chicks (Table 1) by injection of the collected bursal nutrient would seem to confirm

Table I

Primary Antibody Responses to Bovine Serum Albumin (BSA)

	Response - Total		
	Hormonal Group A	Surgical Group B	Normal Group C
Nutrient Injected (1)	4-4	5-5	
Not Injected (2)	0-4	3-5	10-10

the presence of the hypothesized non-cellular, immunocompetence inducing agent. The inconsistant response of the surgically bursectomized, non-injected group (Group B2) may be due to either incomplete removal of the bursa of Fabricius or to a pre-hatching immunological bursal activity (Van Alten *et al.*, 1958, p. 359). Nevertheless, the response of the hormonally bursaless birds would seem to supplement other evidence (Thorbecke *et al.*, 1968, p. 133) which attributes a hormone function to the bursa of Fabricius.

Acknowledgments

We wish to express our thanks to Mr. Frank Failing and the Swedish Covenant Hospital Laboratories for assistance in conducting serological tests.

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OBSERVATIONS OF SOME PHENOTYPIC TRAITS IN *DATURA* SPECIES AND STRAINS

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ABSTRACT. — Some inbred strains of the genus *Datura* obtained from the original Blakeslee stocks, grown at the University of Illinois Drug and Horticultural Experiment Station were studied for a number of morphological and biochemical traits as initial work for a genetic study of the alkaloids of this genus.

Observations were made as to germination rate, measurements of a number of morphological features and semi-quantitative measurements of alkaloid content.

Morphological characters in *Datura* have been the subject of intensive genetic study (Avery, *et al.*, 1959). Not less than 37 phenotypic changes resulting from gene mutations, ploidy changes and extra chromosomal types were reported by the team of 21 workers between 1910 and 1956 and published by Avery *et al.*, 1959 (see Table I). Their reports were largely descriptive and related to the cytogenetics of *Datura*.

In spite of this extensive cytogenetic and morphological work reported on *Datura*, limited reference to the alkaloids has been made. Leete stated that "tests were made of many of the different geographical races as well as the 2n+1 and polyploid forms, which had been assembled by Blakeslee to determine if any showed significantly higher proportions of alkaloids. It was found that environmental factors caused as wide variations as were

TABLE I. Recognized phenotypes due to various genetic conditions

Gene Mutations	*Ploidy Changes*	*Extra Chromosomal Types*
albino	weaker habit	slower growth
pale color	slender stems, branches	poorer in competition
leaf forms	shorter height	wide variation in growth
white flowers	anther changes	mutilated plants
wilted	pollen abortion	broad dark leaves
capsule forms	poor seed formation	flowers short, purple
cotyledon forms	reduced fertilization	capsules globose
habit forms	broad leaves	few short capsule spines
male sterile	large flowers	short, compact plant
pollen abortion	globose capsules	stigma changes— variation
other pollen types	ovate capsules	
pollen tube types	smaller capsules	
miscellaneous	larger capsules	
	enlarged stomata	

Summarized from several chapters, Avery et al., Blakeslee: The Genus *Datura* 1959.

found between specific races'' (Leete, Chapter 3 in Avery, *et al.*, 1959).

In preparation for a genetic study of the mode of inheritance of alkaloids in *Datura*, some observations have been made in this laboratory on the morphology and alkaloid content of now-rare strains (Avery, 1956, James, 1967) available to our experiment station.

It was the object of this work to observe a number of sampled traits and to identify those traits characteristic of the strains to be used in determining the mode of inheritance of the alkaloidal phenotype in *Datura*.

Materials and Methods

Source of Biological Material.—The seeds and their designations are summarized in Table II.

Measurement of Morphological Features.—(a) Germination rate. One hundred seeds of each of the strains tested were germinated in vermiculite at 80°F (26.6°C) after a 10 minute soaking in 1:10 sodium hypochlorite solution. The seeds were washed 3 times with distilled water and allowed to stand overnight in water to soften the testa. Germination counts were made after 40 days. Germinated seedlings were transplanted to a mixture of potting soil and grown in controlled growth rooms at 80°F (26.6°C), 70% relative humidity and full sunlight. Seed stocks were increased in the conventional greenhouse during the spring of 1968.

(b) Final Plant Height, Height of primary stem (to first dichotomy), and number of nodes at harvest. These measurements were made at harvest. Harvesting was performed after dehiscence of the first capsule of a plant.

(c) Organ coloration, anomalous organ development and time of initial floral development. Periodic observations and photographs of these features were taken continuously during development.

(d) Fresh and Dry Weights of Vegetative Organs. Fresh weights of leaf, stem and root were taken at time of harvest. Roots were carefully washed to remove soil. Samples were dried at 50°C (122°F) in forced air ovens for 4 days. Dry weights were taken immediately after the samples were removed from the ovens and cooled.

(e) Capsule Morphology. Measurements were made of the undehisced fruits of the selfed flowers of the various strains. Weights were measured on a torsion balance. Capsule volumes were measured by submerging the weighed capsules in a graduated cylinder of water and observing the change in aqueous volume. The capsules were then opened and counts of the mature seeds were made. Final weight of seeds from each capsule was then measured.

(f) Chemical traits. Extracts of the ground leaves were made (Wu Chu, et al., 1969). Aliquots of the extracts were quantitated by gas chromatography (Solomon, *et al.*, 1969). The results were quantitated using the DS 1 strain as a standard.

Results and Discussion

Although some pure lines of parental stocks, autotetraploids of *Datura stramonium, D. metel, D. inoxia, D. meteloides, D. leichardii* and

TABLE II. Natural history of *Datura* strains.

Our Designation	Original Source	Ploidy Number and Comments	Source	Vitality on Germination
DS 1	Avery Line 1	2 N purple stem purple flowers	A. G. Avery Agr. Expts. Station	92/ /100
DS 3	Avery WF 2	2 N green stem white flowers	U.S.D.A. Expt. Sta. Colorado	58/ /100
DS 5	Blakeslee 530130	2 N purple stem purple flowers	U.S.D.A. Expt. Sta. Colorado	54/ /100
DI 2	Blakeslee 53103	2 N green stem white flowers	U.S.D.A. Expt. Sta. Colorado	82/ /100
DM 2	Blakeslee 480177 (2) (3) (4D)	2 N green stem	U.S.D.A. Expt. Sta. Colorado	68/ /100
DQ 2	Blakeslee 520110	2 N green stem lavender flowers	U.S.D.A. Expt. Sta. Colorado	4/ /100
DS 2	Tetraploid Line 1 PF 4	4 N purple flowers	A. G. Avery Smith Coll. Agr. Expt. Station	88/ /100
DS 4	none given	4 N green stem white flowers	U.S.D.A. Expt. Sta. Colorado	74/ /100
DI 4	Blakeslee 530135	4 N green stem white flowers	U.S.D.A. Expt. Sta. Colorado	42/ /100
DL 4	Blakeslee 530137	4 N green stem yell-white flowers	U.S.D.A. Expt. Sta. Colorado	54/ /100
DMt 4	Blakeslee 510126	4 N lavender-tinged-white flowers must be hand selfed	U.S.D.A. Expt. Sta. Colorado	28/ /100

[1] Letter Designations: DS = *Datura stramonium*, DI = *Datura inoxia*. DM = *Datura metel*, DQ = *Datura quercifolia*, DL = *Datura leichardii*, DMt = *Datura meteloides*.

D. quercifolia were available, their vitality and germination rate were low. These species will be referred to by their initials—see footnote to Table II. The difference in germination rate (Table II) between diploid and autotetraploid strains (all species) was insignificant ($\chi_{(1)}^2 = 0.7542$ n.s.)* (Snedecor and Cochran, 1967). In the diploid strains DQ 2 has a significantly lower germination rate from the other species ($\chi_{(1)}^2 = 156.3714$ $p < .001$). DMt 4 was significantly lower ($\chi_{(1)}^2 = 43.5348$ $p < .001$) than the other tetraploid strains as were DL 4 and DI 4 ($\chi_{(1)}^2 = 11.7966$, $p < .001$). Comparing the diploid *D. stramonium* strains (DS 1, DS 3, DS 5) with the autotetraploid DS strains (DS 2, DS 4) the autotetraploids had a significantly higher germination rate ($\chi_{(1)}^2 = 10.2541$, $p < .001$). It appears that the higher ploidy level may increase germination potential. But when DS 1 vitality on germination is compared with 2 other diploid strains (DS 3, DS 5) significantly higher germination rate is obtained ($\chi_{(1)}^2 = 39.7059$, $p < 0.001$). Thus a particular diploid strain can have a high germination rate without the benefit of an extra chromosome set. The enhanced germination potential is also evident when DI 2 is compared with DI 4 ($\chi_{(1)}^2 = 32.2794$, $p < 0.001$). The diploid and tetraploid strains took about the same time to germinate except for DQ 2 which had low germination rate and long germination time.

The purple stem and lavender flowers of the DS 1 and DS 2 strains appeared together. No formal tests of linkage were made. Avery stated that these traits are monogenic (Avery, 1956). White flowers with green stem appear similar in DS 3 and DS 4 strains. The DS 5 strain has a purple stem and lavender flowers but is a different line from DS 1 and DS 2 (Table II).

Occasional formation of 6 anthers instead of 5 occurred in the DS and DI strains although 5- and 6-anthered flowers occurred on the same plant. This may be a function of the effect of inbreeding on development. Occasional 3 branches occurred at the primary dichotomy in the *D. stramonium* strains.

The DS and DL 4 strains flowered after 11 weeks (both the diploid and autotetraploid varieties). *D. inoxia* took 12 weeks while DM 2, DM 4 and DQ 2 took 17 weeks or longer. To obtain flowers at about the same time for hybridization the DM 2, DMt 4 and DQ 2 must be germinated at least 1 month before the DI strains, and the DI strains should be planted 1-2 weeks before the DS strains.

The DI 2, DI 4 and DMt 4 had fewer flowers but they were comparatively larger than those of the other strains observed.

Although the gross morphology of the various capsules of the strains of *D. stramonium* were indistinguishable (diploid and tetraploid), species differences were characteristic. All species had a fused 5-toothed calyx, forming a collar at the base of the fruit as well as 5 epipetalous stamens and a bifurcated stigma. The immature fruits of *D. stramonium* are somewhat conical. All of the species have a 4-valved fruit with a

* chi-squared having one degree of freedom, i.e., one comparison = 0.7452 — not significant in one choice out of 20.

TABLE III. Measurements of fruit and seed of *Datura* species and strains.

2 N Strains	Volume ml.	Fresh Weight grams	No. of Seeds Geometric Mean[4]	Weight of Seeds (Gm) /Capsule
DS 1 $\overline{X}$[1]	20.64	11.57	312.9	6.35
C.V.[2]	37.65%	66.38%		55.47%
DS 3 $\overline{X}$	31.3	14.49	689.0	8.46
C.V.	23.32%	54.87%		32.10%
DS 5 $\overline{X}$	21.49	12.97	257.2	4.91
C.V.	15.98%	10.35%		17.30%
DI 2 $\overline{X}$	47.34	34.46	446.6	12.30
C.V.	3.76%	12.36%		14.75%
DM 2 $\overline{X}$	30.89	22.73	244.6	7.86
C.V.	22.30%	24.23%		1.20%

4 N Strains	Volume ml.	Fresh Weight grams	No. of Seeds Geometric Mean[4]	Weight of Seeds (Gm) /Capsule
DS 2 $\overline{X}$	10.50	7.83	552.0	2.53
C.V.	18.10%	36.80%		63.2%
DS 4 $\overline{X}$	9.97	13.35	239.0	3.63
C.V.	23.50%	42.10%		50.40%
DI 4 $\overline{X}$	9.48	9.13	83.5	1.14
C.V.	12.89%	9.44		100%

[1] $\overline{X}$ = mean of 6 or more plants measured.

[2] C.V. = coefficient of variation = $\frac{\text{S.D.}}{\overline{X}} \times 100\%$

[3] S.D. = standard deviation = $\frac{(CV)(\overline{X})}{100\%}$

[4] Geometric mean = $\sqrt[n]{x_1 \cdot x_2 \cdot x_3 \cdot \ldots \ldots x_n}$

pseudocarpal wall. The capsule spines are 2-3 cm. long and were lignified except for *D. metel* and *D. leichardii* which remained short and soft.

Capsules of the DI strains were larger than those of DS strains (table III). The fresh seed usually had the funiculus attached as a white appendage on the brown testa. The DI 2 and DI 4 seeds were inbedded in the soft placental tissue whereas seeds of other species and strains dehisced clean from their funiculi.

The DI 4 strain had a smaller capsule than the DS strains (Table III). The capsule of DM 2 was larger than that of the DS strains and was more globular with short blunt spines. DQ 2 had a distinct capsule with spines 3-4 cm. long equipped with lignified tips. Spines of DQ 2 were fewer in number than in the other strains. Within the DS diploid strains, DS 3 had a significantly larger capsule volume than DS 1 or DS 5 ($t_{(18)} = 31.333$, $p < .001$). Volumes of the diploid and tetraploid DS strains were not significantly

TABLE IV. Measurements of elongation and maturation of *Datura* species and strains.

2 N Strains	Final Plant Height cm.	Primary Stem Height cm.	Days to Germination	Days Germination to Flower	Number Nodes at Harvest
DS 1 $\overline{X}$[1]	92.3	24.0	9	78	12.3
C.V.[2]	13.92%	39.7%			4.8%
DS 3 $\overline{X}$	165.7	18.75	10	77	17.30
C.V.	17.24%	23.77%			6.76%
DS 5 $\overline{X}$	177.0	57.60	12	78	16.70
C.V.	12.68%	9.23%			15.86%
DI 2 $\overline{X}$	170.4	71.2	13	85	19.00
C.V.	2.40%	4.91%			5.57%
DM 2 $\overline{X}$	112.60	70.10	17	156	33.90
C.V.	17.1%	21.6%			7.28%
DQ 2 $\overline{X}$	60.00	13.50	26	118	10.00
C.V.	3.3%	40.0%			44.2%

[1] $\overline{X}$ = mean of 6 or more plants measured.

[2] C.V. = coefficient of variation = $\frac{\text{S.D.}}{\overline{X}} \times 100\%$.

TABLE IV (concluded)

4 N Strains	Final Plant Height cm.	Primary Stem Height cm.	Days to Germination	Days Germination to Flower	Number Nodes at Harvest
DS 2 $\overline{X}$	100.68	32.5	9	78	15.0
C.V.	6.73%	18.46%			18.46%
DS 4 $\overline{X}$	192.7	75.30	10	77	18.33
C.V.	0.86%	8.80%			5.45%
DI 4 $\overline{X}$	145.80	74.30	13	91	18.30
C.V.	16.60%	21.94%			4.54%
DL 4 $\overline{X}$	147.7	32.0	18	68	19.0
C.V.	5.79%	10.23%			4.37%

[3] S.D. = standard deviation = $\frac{(CV)(\overline{X})}{100\%}$

[4] Germination was taken as appearance of root apex outside of testa.

[5] Flowering was taken to be appearance of first flower bud.

different ($t_{(69)} = 0.5780$, n.s.). The DI 2 strain, however, was significantly greater in volume than DI 4 ($t_{(78)} = 3.1977$, $p<.01$). The volume of the diploid *D. inoxia* capsule was significantly greater than the DS diploid strains but only at the 5% confidence level ($t_{(89)} = 2.0570$, $p<.05$). Variation in capsule volume within the diploid DS and DI strains was comparable although the large size of DI capsules and the small coefficient of variation (see Table III) appeared to be distinctive for this strain. The *D. metel* capsule volume was significantly smaller than DI 2 ($t_{(63)} = 9.0434$, $p<.001$) but not the DS strains.

Weight of the capsule containing seeds tended to parallel the capsule volume data. Again, DI 2 had the greatest mean weight (Table III) and a low coefficient of variation.

The number of seeds produced was a non-trivial character affecting the potential fecundity of the strains concerned. The diploid DS strains varied greatly among themselves. Within the diploid strains of *D. stramonium* DS 3 had a significantly higher number of seeds produced than DS 1 or DS 5 ($\chi_{(1)}^2 = 13.5084$, $p<.001$). DS 2 (tetraploid) had a significantly higher number of seeds per capsule than DS 1 or DS 5 ($\chi_{(1)}^2 = 43.5915$, $p<.001$). The diploid *D. inoxia* strain had more seeds per capsule than the DI 4 strain ($\chi_{(1)}^2 = 248.71$, $p<<.001$).

Weight of seed per capsule did not appear to be a good criterion. DI 2 had the highest weight of seed with a moderate coefficient of variation, but the other diploid strains were

inconspicuous for this trait. The tetraploid strains appeared to vary tremendously in weight of seed.

The number of nodes at harvest (Table IV) appear to be quite specific for each strain as indicated by the coefficient of variation for both the diploid and autotetraploid strains of all the species studied. No explanation of the large variation in the DQ 2 strain is available.

Final plant height (Table IV) is another trait demonstrating low variation and high specificity for the species studied. No evidence of gigantism in the plant trait is evident in the autotetraploid strains of *D. stramonium* or *D. inoxia*.

Height of primary stem (to the primary dichotomy) was not a reliable criterion for all species or even for DS strains within the *D. stramonium* species (Table IV).

The dry weights of leaf and root for the diploid strains appeared to vary more than the fresh weights (Table V). This effect was not noticeable in the autotraploid strains (Table V). Fresh and dry weights of leaves appeared to be the only traits consistently demonstrating moderate variation. The fresh and dry weights of stem, root and total plant tissue were subject to sporadic extreme variations and were generally less reliable. The obvious effects of gigantism can be seen by comparing the mean fresh weight of leaf from diploid strains and their respective autotetraploid strains. These gigantic effects are also noticeable when mean dry weights of diploid and autotetraploid leaf are compared (DS 1 vs. DS 2, DS 3 vs. DS 4, DI 2 vs. DI 4).

An initial study of the strains producing atropine and scopolamine indicated that the 3 inbred strains of *Datura* (DS 1, DS 3, DS 5) differed in alkaloid content (Table VI) with DS 5 differing markedly from the others. The autotetraploid strains had greater amounts of both atropine and scopolamine than the diploid *D. stramonium* strains as previously reported by Rowson 1944.

This report extends the observations of Rowson 1944 that increased alkaloid content occurs in *D. stramonium* autotetraploids. Autotetraploids in *D. inoxia* are also now known and this chemical gigantism is present in DI 4 to the extreme.

The tetraploid strains DS 2 and DS 4 produced more atropine and scopolamine than their corresponding diploid strains DS 1 and DS 3 but not much higher than DS 5. This indicated that it is possible for a diploid strain to produce about as much alkaloid as strains with higher ploidy levels.

In view of larger weights of leaf material and larger percentages of atropine and scopolamine in the autotraploid strains studied it would appear that growth of these strains should result in increased alkaloid yields for commercial use.

A summary of the various phenotypes of the strains under study is found in Table VII.

TABLE V. Measurements of weighed plant organs of *Datura* species and strains.

2 N Strains	Fresh Weight (grams)				Dry Weight (grams)			
	Leaf	Stem	Root	Total Plant	Leaf	Stem	Root	Total Plant
DS 1 $\overline{X}$[1]	127.0	173.0	333.0	862.0	25.17	43.27	90.2	158.67
C.V.[2]	21.8%	2.61%	2.93%	6.70%	31.98%	4.00%	20.48%	14.58%
DS 3 $\overline{X}$	124.4	189.0	408.0	612.0	22.40	45.40	108.0	127.5
C.V.	53.07%	15.92%	62.31%	50.57%	11.31%	50.47%	75.50%	40.94%
DS 5 $\overline{X}$	209.9	358.0	864.6	1619.1	34.70	104.41	164.0	303.11
C.V.	3.15%	37.70%	12.10%	11.70%	20.85%	38.59%	80.68%	89.21%
DI 2 $\overline{X}$	276.0	447.4	770.4	1844.8	58.67	107.48	99.35	266.44
C.V.	11.73%	10.10%	50.90%	73.3%	12.94%	14.61%	17.82%	3.77%
DM 2 $\overline{X}$	355.9	318.6	1071.0	1884.10	54.10	80.34	274.0	414.74
C.V.	11.90%	23.90%	20.80%	6.32%	16.27%	27.26%	46.96%	98.13%

4 N Strains	Fresh Weight (grams)				Dry Weight (grams)			
	Leaf	Stem	Root	Total Plant	Leaf	Stem	Root	Total Plant
DS 2 $\overline{X}$	223.5	228.5	402.5	849.5	34.25	56.50	68.50	159.35
C.V.	7.72%	4.82%	16.14%	7.68%	7.88%	1.76%	40.0%	68.31%
DS 4 $\overline{X}$	139.5	181.0	457.0	967.0	35.90	53.95	105.45	195.30
C.V.	63.80%	12.97%	34.44%	34.44%	26.74%	17.98%	27.59%	64.36%
DI 4 $\overline{X}$	378.2	320.7	961.7	1719.0	70.96	84.85	248.23	265.00
C.V.	11.58%	17.50%	32.30%	21.30%	17.05%	48.36%	9.99%	39.52%

[1] $\overline{X}$ = mean of 6 or more plants measured.

[2] C.V. = coefficient of variation = $\frac{\text{S.D.}}{\overline{X}} \times 100\%$

[3] S.D. = standard deviation = $\frac{(CV)(\overline{X})}{100\%}$

TABLE VI. Alkaloid content of leaves relative to that of strain DS 1.

Strain	Per Cent Atropine	Per Cent Scopolamine	Per Cent Total Alkaloids
DS 1 2 N	100%[1]	100%	100%
DS 2 4 N	163.8%	141.0%	158.7%
DS 3 2 N	88.5%	79.5%	90.4%
DS 4 4 N	165.0%	107.0%	153.5%
DS 5 2 N	164.2%	124.0%	146.0%
DI 2 2 N	3.87%	189.0%	70.0%
DI 4 4 N	66.5%	519.0%	157.0%

[1] Each percentage listed is the mean of 2 determinations.

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TABLE VII. Summary of phenotypic observations on Datura species and strains.

Strain	Vitality	Capsule Weight	Capsule Volume	Seed Number	Seed Weight	Height	Days to Germination	Days to Flower	Nodes	Fresh Weight			Dry Weight			Alkaloids		
										Leaf	Stem	Root	Leaf	Stem	Root	Atr.	Scop.	Total
2 N																		
DS 1	+++	++	++	++	+	++	+	+	+	+	+	+	+	+	+	++	++	++
DS 3	++	++	+++	+++	+	+++	+	+	+	+	+	+	+	+	+	+	+	+
DS 5	++	++	++	+	+	+++	+	+	+	++	+++	+++	++	+++	+++	+++	++	++
DI 2	+++	+++	+++	++	++	+++	++	++	+	++	+++	+++	+++	+++	++	0	++	+
DM 2	++	++	+++	+	+	++	++	+++	+++	+++	+++	+++	+++	++	+++	—	—	—
DQ 2	0	—	—	—	—	+	+++	+++	+	—	++	—	—	—	—	—	—	—
4 N																		
DS 2	+++	+	+	+++	+	++	+	+	+	++	++	+	++	+	+	+++	++	++
DS 4	++	+	+	+++	+	+++	+	+	+	+	+	+	++	+	+	+++	+++	++
DI 4	++	+	+	0	0	+++	++	++	+	+++	+++	++	+++	++	++	+	+++	++
DL 4	++	—	—	—	—	+++	++	+++	—	—	—	—	—	—	—	—	—	—
DNt 4	+	—	—	—	—	—	—	+++	—	—	—	—	—	—	—	—	—	—

DS 1 set arbitrarily as standard for a given trait.
+++ = highest, largest, longest, most concentrated; ++ = moderate; + = fair; 0 = very low or absent; — = notsampled.

LICHENOLOGICAL RECORDS FROM CENTRAL AND NORTHERN ILLINOIS

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ABSTRACT. — Fifty-one species are reported; 17 are new to the known flora of Illinois. Literature concerning the Illinois lichen flora is summarized.

Publications pertaining to lichens of Illinois are: Tuckerman (1866), Willey (1877, 1878, 1890), Wolf & Hall (1878), Brendel (1887), Müller (1889), Calkins (1896), Fink (1899, 1900, 1906, 1935), Magnusson (1929, 1934, 1944, 1947), Hedrick (1933), Hartline (1938), Berry (1941), Llano (1950), Servit (1950a, 1950b), Thomson (1950, 1963, 1968), Imshaug (1951, 1957), Hale (1952, 1955, 1956, 1958, 1962, 1964, 1965), Degelius (1954), Rudolph (1955), Kurokawa (1962), Henssen (1963), Hale & Kurokawa (1964), Sierk (1964), Imshaug & Brodo (1966), and Skorepa & Snider (1967). The 51 species reported here were collected mainly by myself in the fall of 1968. Seventeen species are newly reported from Illinois; almost all of the reports represent county records. Specimens are at SIU. Names preceded by an asterisk are new to Illinois.

**Allarthonia caesia* Flot. BUREAU CO.: Kasbeer, *5167*. OGLE CO.: White Pines Forest State Park, *5055*. STEPHENSON CO.: Lake Le-Aqua-Na State Park, *5046*. Found on *Juglans*, *Populus*, and *Prunus*; common on trees throughout the state.

**Arthopyrenia biformis* (Borr.) Mass. JERSEY CO.: Stump Lake, *5125*. Found on *Carya* in the open.

Bacidia inundata (Fr.) Körb. JERSEY CO.: Grafton, *5084*. On limestone on a dry slope.

Buellia punctata (Hoffm.) Mass. OGLE CO.: White Pines Forest State Park, *5056*. WILL CO.: Lorenzo, *Skorepa & Vermoch 5215*. On *Quercus* and *Prunus*.

Caloplaca flavovirescens (Wulf.) Dalla Torre & Sarnth. CALHOUN CO.: 5 mi. S of Hardin, *5063*. On limestone.

Caloplaca microphyllina (Tuck.) Hasse. BUREAU CO.: Kasbeer, *5168*. FULTON CO.: 5 mi. W. of Havana, *5018*. STEPHENSON CO.: Lena, *5159*. On fence posts.

Candelaria concolor (Dicks.) B. Stein. BUREAU CO.: 1 mi. S of Ohio, *5053*. CALHOUN CO.: Kampsville, *5098*; 5 mi. S of Hardin, *5066*. FULTON CO.: 5 mi. W. of Havana, *5019*. JERSEY CO.: Stump Lake, *5126*. JO DAVIESS CO.: Stockton, *5121*. LA SALLE CO.: Starved Rock State Park, *5184*. LEE CO.: Green River Conservation Area, *5028*. SANGAMON CO.: Springfield, *5212*. STEPHENSON CO.: 8 mi. N of Ridott, *5109*. WILL CO.: Lorenzo, *Skorepa & Vermoch 5222*. The common yellow lichen of trees and fence posts throughout the state.

Candelariella vitellina (Ehrh.) Müll. Arg. OGLE CO.: Castle Rock *5181*. On vertical sandstone in full sun.

Cladonia caespiticia (Pers.) Flörke. FAYETTE CO.: Ramsey Lake State Park, *5115*. On soil in dry woods.

Cladonia cristatella Tuck. WILL CO.: Lorenzo, *Skorepa & Vermoch 5214*. On old wood in a field.

**Cladonia decorticata* (Flörke) Spreng. WILL CO.: Lorenzo, *Skorepa & Vermoch 5225*. On old wood in a field.

Cladonia furcata (Huds.) Schrad. LA SALLE CO.: Starved Rock State Park, *5149*. On a soil bank in dry woods.

Cladonia pyxidata (L.) Hoffm. FAYETTE CO.: Ramsey Lake State

Park, *5116*. OGLE CO.: Castle Rock, *5024*. Found on soil in dry places.

**Cladonia robbinsii* Evans. OGLE CO.: Castle Rock, *5025*. Over soil on a dry slope.

**Cladonia subtenuis* (Abb.) Evans. FAYETTE CO.: Ramsey Lake State Park, *5117*. On soil in dry woods.

Cladonia uncialis (L.) Wigg. OGLE CO.: Castle Rock, *5023*. Over soil on a dry slope.

Cyphelium tigillare (Ach.) Ach. JERSEY CO.: Grafton, *5118*. LEE CO.: Green River Conservation Area, *5029*. MACOUPIN CO.: Piasa, *5051*. MONTGOMERY CO.: Litchfield, *5093*. A common greenish yellow crust on fence posts and old wood throughout Illinois.

Dermatocarpon miniatum (L.) Mann. CALHOUN CO.: 5 mi. S of Hardin, *5061*. On limestone in full sun.

Endocarpon pusillum Hedw. JERSEY CO.: Grafton, *5079*. Found on limestone on a dry slope, filtered sun.

Graphis scripta (L.) Ach. FAYETTE CO.: Ramsey Lake State Park, *5158*. On *Carya* in dry woods.

Heterodermia tremulans (Müll. Arg.) W. Culb. LA SALLE CO.: Starved Rock State Park, *5189*. On white oak in dry woods.

**Lecanora dispersa* (Pers.) Somm. CALHOUN CO.: 5 mi. S of Hardin, *5062*. COOK CO.: Riverside, *5224*. WILL CO.: Lorenzo, *Skorepa & Vermoch 5218*. On rocks and concrete.

**Lecanora rubina* (Vill.) Ach. OGLE CO.: Castle Rock, *5179*. Rare in Illinois. At Castle Rock this species grows with *Candelariella vitellina* and *Rinodina oreina* on the most severely exposed sandstone.

Lecanora symmicta (Ach.) Ach. WILL CO.: Lorenzo, *Skorepa & Vermoch 5216*. On oak wood in a field.

Lecidea flexuosa (Fr.) Nyl. WILL CO.: Lorenzo, *Skorepa & Vermoch 5218*.

**Lecidea russellii* Tuck. JO DAVIESS CO.: Apple River Canyon State Park, *5200*. On limestone.

Lecidea uliginosa (Schrad.) Ach. WILL CO.: Lorenzo, *Skorepa & Vermoch*, *5217*. On oak wood in a field.

Parmelia aurulenta Tuck. FAYETTE CO.: Ramsey Lake State Park, *5190*. OGLE CO.: White Pines Forest State Park, *5142*. Found on *Fraxinus* and *Quercus;* common on trees and on sandstone in southern Illinois.

**Parmelia bolliana* Müll. Arg. LA SALLE CO.: Starved Rock State Park, *5171*, *5185*. LEE CO.: Green River Conservation Area, *5133*. MARSHALL CO.: Henry, *5074*. OGLE CO.: Castle Rock, *5057*. Common on trees in dry places.

Parmelia caperata (L.) Ach. JO DAVIESS CO.: Apple River Canyon State Park, *5127*. LA SALLE CO.: Starved Rock State Park, *5192*. LEE CO.: Green River Conservation Area, *5131*. OGLE CO.: Castle Rock, *5073*. STEPHENSON CO.: Ridott, *5150*. Common on sandstone and on trees throughout the state.

**Parmelia dierythra* Hale. OGLE CO.: Castle Rock, *5067*. On horizontal sandstone in full sun.

**Parmelia hypoleucites* Nyl. OGLE CO.: White Pines Forest State Park, *5138*. On *Fraxinus*; also found on sandstone in southern Illinois.

Parmelia rudecta Ach. FAYETTE CO.: Ramsey Lake State Park, *5174*. JO DAVIESS CO.: Apple River Canyon State Park, *5041*. FULTON CO.: 6 mi. W of Havana, *5022*. LA SALLE CO.: Starved Rock State Park, *5186*. LEE CO.: Green River Conservation Area, *5132*. MASON CO.: Chautauqua National Wildlife Refuge, *5035*. OGLE CO.: White Pines Forest State Park, *5103*. WINNEBAGO CO.: 3 mi. N of Pecatonica, *5002*. Very common on trees and sometimes rocks throughout Illinois.

**Parmelia subrudecta* Nyl. MASON CO.: Chautauqua National Wildlife Refuge, *5204*. OGLE CO.: Castle Rock, *5072*. Found on oaks in dry woods.

Parmelia sulcata Tayl. LEE CO.: Green River Conservation Area, *5130*. STEPHENSON CO.: Lake Le-Aqua-Na State Park, *5049*. On *Quercus* and *Juglans*.

Peltigera canina (L.) Willd. FAYETTE CO.: Ramsey Lake State Park, *5177*. LA SALLE CO.: Starved Rock State Park, *5147*. A typical species of soil in dry, hilly woods.

Physcia aipolia (Ehrh.) Hampe. CARROLL CO.: Mt. Carroll, *5075*. JO DAVIESS CO.: Stockton, *5112*. LA SALLE CO.: Starved Rock State Park, *5170*. OGLE CO.: White Pines Forest State Park, *5124*; Adeline, *5135*; Castle Rock, *5091*. WINNEBAGO CO.: 3 mi. N of Pecatonica, *5001* (f. *cercida* (Ach.) Mig.). Found on various trees, usually soft-barked species, in open places. The specimens from northern Illinois are more

robust than those from southern Illinois.

Physcia ciliata (Hoffm.) DR. CALHOUN CO.: Kampsville, *5203*. JO DAVIESS CO.: Apple River Canyon State Park, *5008*. On Populus in open places.

**Physcia elaeina* (Sm.) A. L. Sm. STEPHENSON CO.: 8 mi. N of Ridott, *5108*. Found on *Ulmus* at the edge of a woods.

Physcia grisea (Lam.) Zahlbr. JO DAVIESS CO.: Apple River Canyon State Park, *5110*. LA SALLE CO.: Starved Rock State Park, *5169*. OGLE CO.: White Pines Forest State Park, *5141*; Castle Rock, *5092*. On *Fraxinus*, *Populus*, and *Quercus alba* in dry woods.

**Physcia lacinulata* Müll. Arg. JO DAVIESS CO.: Apple River Canyon State Park, *5195*. Over moss on mostly shaded limestone. Thomson (1963) cited 5 specimens of *P. lacinulata* distributed in Georgia, North Carolina, and Wisconsin. It now appears to be a much more common eastern North American species. McCullough (1964, 1967) cited several specimens from Alabama. Taylor (1967) reported it as widespread in Ohio, and I have found it to be very common on white oaks in southern Illinois. It is, however, apparently absent from the Ozark Mountains (Hale, 1957), from Florida (Moore, 1968), and from Long Island, New York (Brodo, 1968).

Physcia millegrana Degel. BUREAU CO.: Kasbeer, *5165*; 1 mi. S of Ohio, *5054*. CALHOUN CO.: Kampsville, *5095*. FAYETTE CO.: Ramsey Lake State Park, *5176*. FULTON CO.: 5 mi. W of Havana, *5017*. JERSEY CO.: Grafton, *5119*. JO DAVIESS CO.: Apple River Canyon State Park, *5042*. LA SALLE CO.: Starved Rock State Park, *5188*. LEE CO.: Green River Conservation Area, *5134*. MARSHALL CO.: Henry, *5075*. MASON CO.: Chautauqua National Wildlife Refuge, *5034*. OGLE CO.: Castle Rock, *5086*. SANGAMON CO.: Springfield, *5310*. STEPHENSON CO.: Lena, *5160*; Lake Le-Aqua-Na State Park, *5048*. WILL CO.: Lorenzo, *Skorepa & Vermoch 5211*. WINNEBAGO CO.: 3 mi. N of Pecatonica, *5003*. Found on trees and fence posts throughout the state; also common on sandstone in southern Illinois. This is probably the most common lichen in Illinois.

Physcia orbicularis (Neck.) Poetsch. JO DAVIESS CO.: Apple River Canyon State Park, *5038*. OGLE CO.: White Pines Forest State Park, *5104*. STEPHENSON CO.: 8 mi. N of Ridott, *5107*. On *Juniperus*, *Quercus*, and *Tilia*.

Physcia stellaris (L.) Nyl. BUREAU CO.: 1 mi. S of Ohio, *5052*. CALHOUN CO.: Kampsville, *5096*. FULTON CO.: 5 mi. W of Havana, *5020*. JERSEY CO.: Grafton, *5080*. JO DAVIESS CO.: Stockton, *5113*. LEE CO.: Green River Conservation Area, *5032*. STEPHENSON CO.: Ridott, *5151*. WILL CO.: Lorenzo, *Skorepa & Vermoch 5221*. Common on trees in open places.

Physcia syncolla Tuck. CALHOUN CO.: Kampsville, *5099*. JO DAVIESS CO.: Apple River Canyon State Park, *5015*. STEPHENSON CO.: Lake Le-Aqua-Na State Park, *5045*. WINNEBAGO CO.: 3 mi. N of Pecatonica, 5000. Found on *Juglans* and *Populus* in open places.

**Physcia tribacoides* Nyl. CALHOUN CO.: Kampsville, *5097*. FAYETTE CO.: Ramsey Lake State Park, *5172*. JO DAVIESS CO.: Apple River Canyon State Park, *5143*. Found on *Populus* and *Quercus*.

Placynthium nigrum (Huds.) S. Gray. CALHOUN CO.: 5 mi. S of Hardin, *5064*. JERSEY CO.: Grafton, *5083*. On limestone.

Pyxine sorediata (Ach.) Mont. FAYETTE CO.: Ramsey Lake State Park, *5191*. On *Quercus rubra* in dry woods.

Rinodina oreina (Ach.) Mass. OGLE CO.: Castle Rock, *5180*. On vertical sandstone in full wind and sun.

**Sarcogyne simplex* (Dav.) Nyl. OGLE CO.: Castle Rock, *5068*. On horizontal sandstone in full sun.

**Xanthoria fallax* (Hepp) Arn. CALHOUN CO.: Kampsville, *5094*. CARROLL CO.: Mt. Carroll, *5078*. JO DAVIESS CO.: Stockton, *5111*. WINNEBAGO CO.: 3 mi. N of Pecatonica *5006*. On roadside trees.

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THERMAL STUDIES ON PHASE TRANSITIONS IN SOME SODIUM, POTASSIUM, AND SILVER COMPOUNDS

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ABSTRACT. — Enthalpies of the phase transitions in solid potassium nitrite, potassium thiocyanate, sodium nitrite, and silver nitrate have been determined using differential scanning calorimetry. The corresponding enthalpies are 199 ± 2, 397 ± 4, 299 ± 33, and 555 ± 5 cal/mole respectively. The enthalpies determined for the phase transitions in silver nitrate and sodium nitrite are in good agreement with previously reported values while those for potassium thiocyanate and potassium nitrite do not agree with older values. Observations are presented on the thermal changes in $Na_2Cr_2O_7 \cdot 2H_2O$ during dehydration.

A large number of phase transitions are known to occur when salts are heated in the solid state (Rao and Rao, 1967). Of particular note are the familiar phase transitions in solid ammonium halides. However, because of the difficulty in studying the thermal changes during these transitions, there is frequently disagreement on the enthalpy change associated with the phase changes. Therefore, even for some common compounds, the enthalpies are not accurately known. Accordingly, we have determined the enthalpies associated with transitions in solid potassium thiocyanate, potassium nitrite, sodium nitrite, and silver nitrate. As a result of the attempted study of phase transitions in sodium dichromate, the kinetics and thermal changes accompanying the dehydration of sodium dichromate dihydrate have been determined.

METHODS AND MATERIALS

All compounds used were of reagent grade and were used without further chemical purification. These crystalline compounds were freshly ground to a fine powder before use. The $Na_2Cr_2O_7 \cdot 2H_2O$ was finely powdered and a sample placed in an oven at 110° for several days to determine the total amount of water of hydration present. The calculated weight loss for dehydration is 12.08% and the observed weight loss was 12.16%.

Enthalpies of the phase transitions and the dehydration of $Na_2Cr_2O_7 \cdot 2H_2O$ were determined using a Perkin-Elmer Differential Scanning Calorimeter, Model DSC-1B. The instrument was calibrated against the fusion of metallic tin with a heat of fusion of 14.5 cal/g. The system was purged with dry nitrogen at a flow rate of 15 cc/min. Samples of about 2-5 mg weighed to six decimal places were used and the endothermic peak areas were determined by graphical integration.

Results and Discussion

The enthalpy changes obtained for the phase transitions studied are shown in Table 1. The compounds studied were chosen because of the approximate nature of values previously reported or because there were large discrepancies between two or more reported values. It is readily apparent that the values obtained in this study agree well with one or more previously reported values for the phase transitions in silver nitrate and sodium nitrite. It is also obvious that the older values for transitions in potassium thiocyanate and potassium nitrite are greatly different from those in this work and outside our limits of error. The limits of error for the experimental procedures used in this work make it possible to unequivocally eliminate some of the previously reported values which were determined by techniques much less accurate than differential scanning calorimetry. The physical nature of the transitions in these compounds has been discussed in the references in Table 1 and will not be reviewed here.

It was hoped that the phase transitions in $Na_2Cr_2O_7$ could also be studied (Popov and Galchenko, 1951). However, only peaks of variable size and at irregular temperatures could be obtained between 385-500°K. The reason for this behavior is not known. In several thermograms, peaks corresponding to phase transitions were found at 420, 434, and 443°K, but these were not present in all runs.

It has been possible to study carefully the dehydration of $Na_2Cr_2O_7 \cdot 2H_2O$. Previously, only a qualitative study of the dehydration has been reported (Erday, *et al.*, 1966) and no kinetic or thermodynamic values were reported. These workers reported that the two moles of water of crystallization are removed by 300°C. In all our runs, the dehydration was complete by 120°C and was accompanied by an enthalpy change of 15.9 ± 0.8 kcal/mole. Using the procedure of Thomas and Clarke (1968), we have determined the activation energy for the dehydration to be 15.0 ± 0.8 kcal/mole.

Table 1. Enthalpy Changes for Phase Transitions.

Compound	Transition Temperature, °C	Number of Determinations	Enthalpy Change, cal/mole: This Work[a]	Enthalpy Change, cal/mole: Literature	Reference
KSCN	140	4	397 ± 4	530	b
$NaNO_2$	160	5	299 ± 33	~285, ~250	c, d
KNO_2	40	5	199 ± 2	~100	d
$AgNO_3$	160	3	555 ± 5	584, 561, 920	e, f, g

[a] Given as average value ± average deviation from the mean.
[b] Sakiyama, *et al.*, 1963
[c] Nomura, 1961
[d] Rao and Rao, 1966A
[e] Janz and Kelly, 1963
[f] Reinsborough and Wetmore, 1967
[g] Rao and Rao, 1966B

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ALKALOIDS IN THE GERMINATING SEEDLING OF POPPY

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ABSTRACT. — Seedlings of the commercial "blue" strain of *Papaver somniferum L.* were germinated in culture dishes on wet gauze. Eleven gram or larger samples (f.wt.) were killed on successive days, extracted and chromatographed on silica gel G plates (0.25 mm.) in the following system: xylene, ethylmethylketone, methanol and diethylamine (20:20:3:1). Color development was with Dragendorff's reagent.

By the 3rd day of germination traces of morphine, codeine, thebaine, papaverine and narcotine could be detected. On the 5th day traces of possible reticuline could be seen, and narcotoline was suspected on the 6th day. Though all of the compounds increased in the extracts with increasing days up to the 9th day, the largest spots were thebaine, papaverine and narcotine. Difference in alkaloid composition between seedling and capsule was largely that of concentration. The seedlings contained much lower concentrations of all alkaloids observed.

Attempts were made to study development of these compounds by feeding C^{14} sucrose and tyrosine at the beginning of germination, but incorporation into these alkaloids was so slight that results were not conclusive.

The alkaloids of poppy (*Papaver somniferum L.*) are located in the laticifers of the plant. Identification and study of these compounds generally involves isolation from the vegetative parts (root, stem, leaves) and especially the developing capsules. It is commonly believed that poppy seeds do not contain alkaloid compounds, probably related to the fact that laticifers have not developed in the embryo of the mature seed. By far the greatest amount of latex and alkaloid content is present in the pericarp and placentae during the period in which fertilized ovules are developing into seeds. Speculation on this condition has led to the idea that substances non-alkaloidal in nature must be passed from the placenta to the developing seeds. Alcoholic extracts of poppy seeds do not contain any substance which reacts with Dragendorff's reagent.

Germinated seedlings contain alkaloids beginning at the 3rd day after water is applied to the seeds. Though the seedling is very small (average weight per seed 0.54 mg.; average dimensions of seed 0.96 x 1.5 x 0.5 mm.) large numbers of seedlings of a single strain may be pooled for experimental work since development is very uniform. Many studies have been made of the alkaloidal composition of the mature plant (Mary, N. Y. and Brochmann-Hanssen, 1963; Genest, K. and Farmilo, 1962) while very few have attempted to characterize the alkaloids of the seedling (Massicot, J. 1961)

In this present work we have re-examined the changing alkaloidal picture during seedling development and attempted to discover whether the alkaloids are synthesized from

glucose or tyrosine in these early stages of growth and to relate our results to work on the possible importance of alkaloids to seed viability.

Materials and Methods

Seeds of the commercial Blue Strain of poppy were soaked in 1-10 hypochlorite-water for 10 minutes and washed with 5 changes of distilled water. Four grams of seed were evenly spread on the water moistened surface of cotton gauze on the bottom of a deep 6″ diameter culture dish. The glass cover was set in place and the dishes were located on a laboratory windowsill so that they would receive sunlight. Covers were removed periodically to allow air change, and water was added by pipette to keep the gauze moist but avoid pools of water. Sunlight for short periods was desirable, but caused condensation which was harmful if dripped directly on the seedlings. Dishes were observed and adjusted several times daily. Emergence of the root began by 48 hours after water was added, and a root system was observed by 3 days. Cotyledons could be seen at 4 days. Germination proceeded until the cotyledons were 7 cm. above the root at 9-10 days.

At harvest, the seedlings were immersed in a killing bath of 5 ml. 5% acetic acid in 100 ml. 70% methanol. Care was taken to remove roots from the gauze with fine forceps. Maceration in the fixing bath continued for 48 hours after which seedlings were triturated in a mortar and pestle or ground in a blendor, then filtered through a Büchner funnel combining all washings. The solution was made alkaline to pH 8. with dry powdered sodium bicarbonate in a separatory funnel. It was then extracted with 4 to 5 successive 30 ml. portions of ethyl acetate. The combined ethyl acetate extract was evaporated to dryness at reduced pressure and the methanol-water extract was also evaporated.

An alternative system used for extraction of seedlings included the following. Seedlings were killed in 95% ethanol, macerated, ground and filtered. The pH was adjusted to acid range with 0.1 N hydrochloric acid and the solution was extracted with several portions of ethyl acetate to remove pigments and lipids. Ammonium hydroxide was added to bring the pH above 7.6 and 5 successive extractions were made using chloroform 3 parts to isopropanol 1 part, the aliquots 30, 20, 20, 20, 10 ml. These fractions were combined, were washed with water, then evaporated to dryness under reduced pressure. The water-soluble extract was also reduced to dryness. Each of the dried extracts were taken up in 2.0 ml. of methanol and held for chromatographic separation.

Extracts were chromatographed on thin layer plates of silica gel G (250 microns) spread by the DeSaga apparatus and activated at 105° for 30 minutes. One-tenth to 0.2 of the 2 ml. of extract (representing about 1000 seedlings) chromatographed satisfactorily.

Plates were developed in the following solvent system in a saturated atmosphere of xylene, ethylmethylketone, methanol, diethylamine (20:20:3:1). Development occurred in 35-40 minutes. The solvent front

was marked immediately upon removal of the plate from the developing tank.

Color was revealed by use of the modified Dragendorff's solution which was sprayed lightly over the entire plate, followed by mild heating. Alkaloids appeared as orange-red spots against a yellow background. Concentrations required that certain alkaloids receive a second spraying with Dragendorff's reagent. Spots were circled immediately after development.

Results and Discussion

Seeds were originally soaked in dilute hypochlorite solution and rinsed to eliminate molds which hinder germination. During the 24 hours the seeds had swollen to approximately double their original size. On the second day of germination emergence of the root occurred as enlargement of the germinating seed continued. Root length was about 2 cm. on the 3rd day and the cotyledons had begun to emerge from

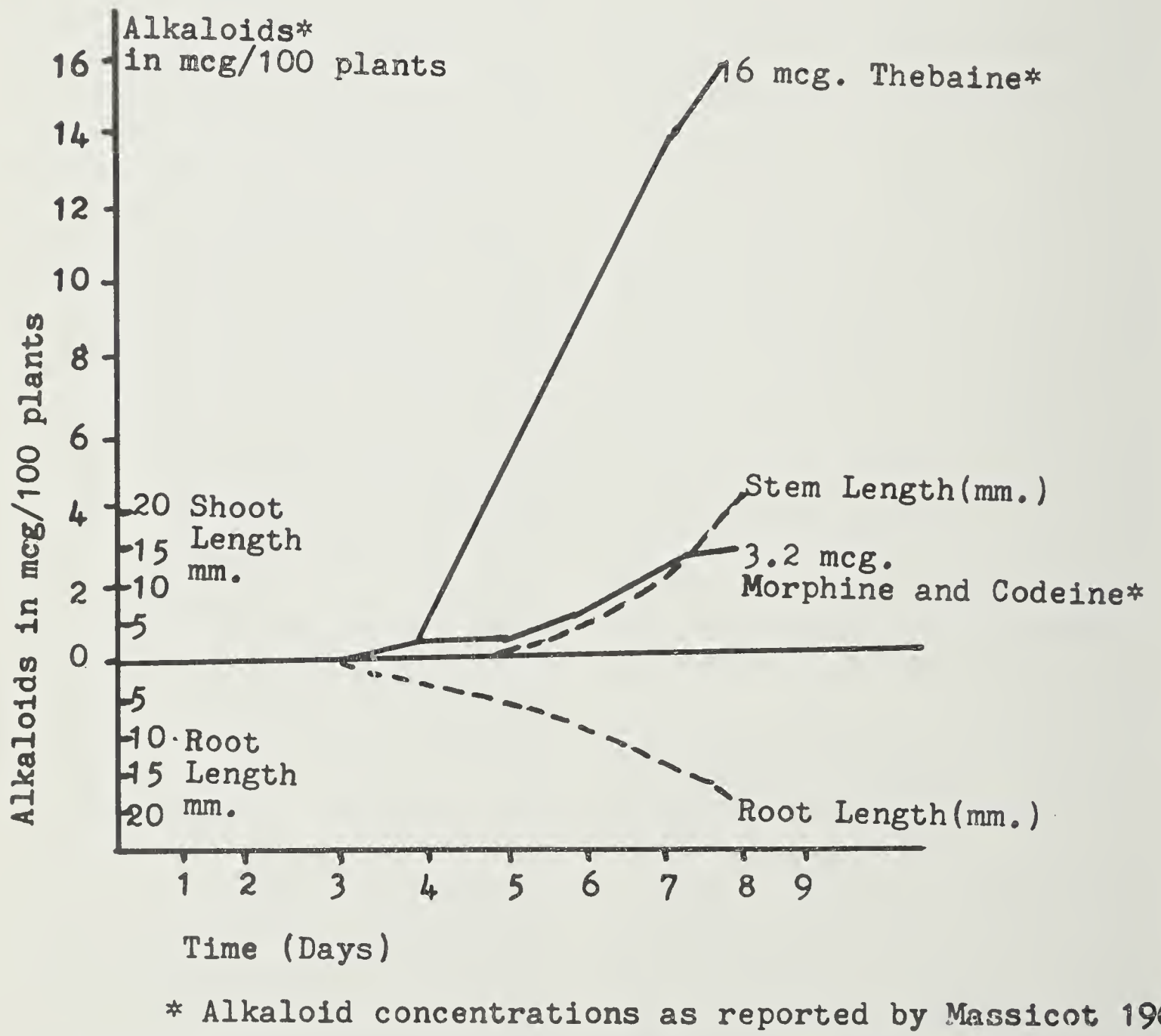


Figure 1. Growth of seedlings and production of alkaloids during the course of germination of poppy (*Papaver somniferum* L.).

the seed coat. Fourth day seedlings bore roots of 3-4 cm. length and shoots of 5.6 mm. On the 5th day the shoot stood erect, about 2 cm. in height; the root was 5-6 cm. in length. The 6th day seedlings had cotyledons well expanded, were green in color, and were about 3-4 cm. tall. Roots were 6-8 cm. in length and had grown intertwined through the gauze substrate. Seventh, 8th and 9th days saw seedlings continue to the extent of their growth in the dishes. Maximum shoot length was around 5 cm. and maximum root length was 8 cm. At no time did the primary growing point give rise to leaves beyond the stage of expanded cotyledons.

The presence of alkaloids in the seedlings followed the pattern shown in Figure 1.

No Dragendorff reactive material was found present in ground seeds of Blue Strain poppy regardless of the amount of seed used. This was also true after 24 hours of germination. On the 2nd day of germination the extract from a very large number of seedlings contained substances which reacted with the Dragendorff reagent but these were not resolved as discrete spots. Several samples of this extract were chromatograph-

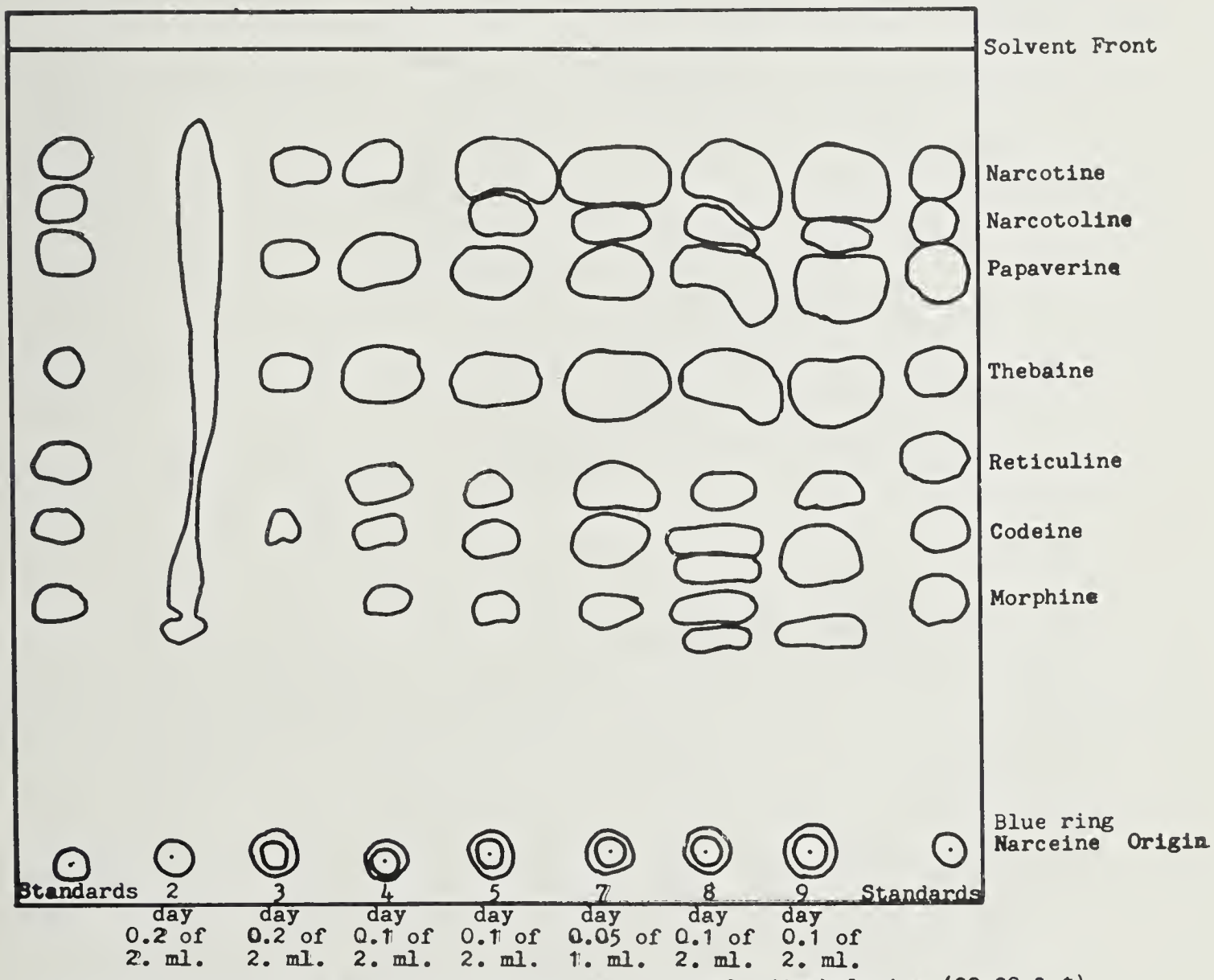


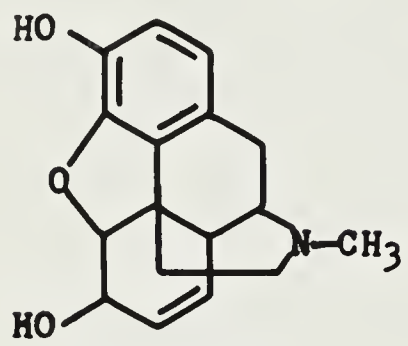
FIGURE 2. Composite of thin layer chromatograms of extracted seedlings of poppy (*Papaver somniferum* L.).

ed, but the streaks were not resolved.

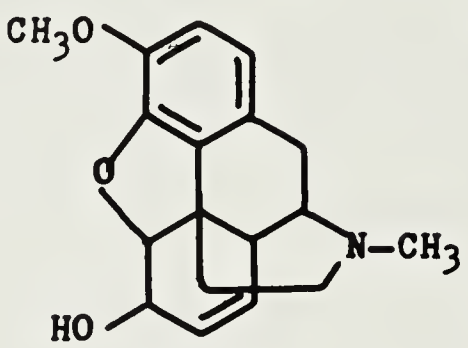
Third day seedlings contained small but definite amounts of codeine, thebaine, papaverine, and narcotine with traces of presumably narcotoline and reticuline. Narceine, a water-soluble alkaloid, was also present in trace amount at the original point of application on the chromatogram (Figs. 2 and 3).

Extracts from 4th day seedlings produced larger, more definite spots of thebaine, papaverine, narcotine, narcotoline and reticuline, and in addition had small amounts of codeine and morphine present.

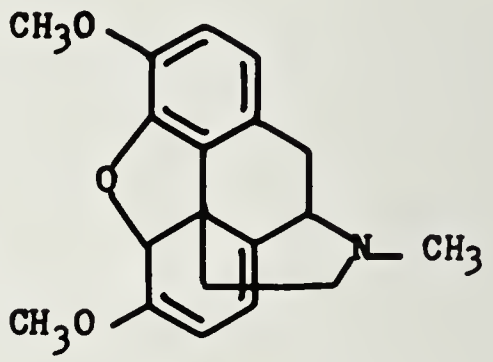
Fifth day seedlings contained all of the alkaloids previously mentioned in larger amounts for the amount of extract used to prepare the plates was half of that for the



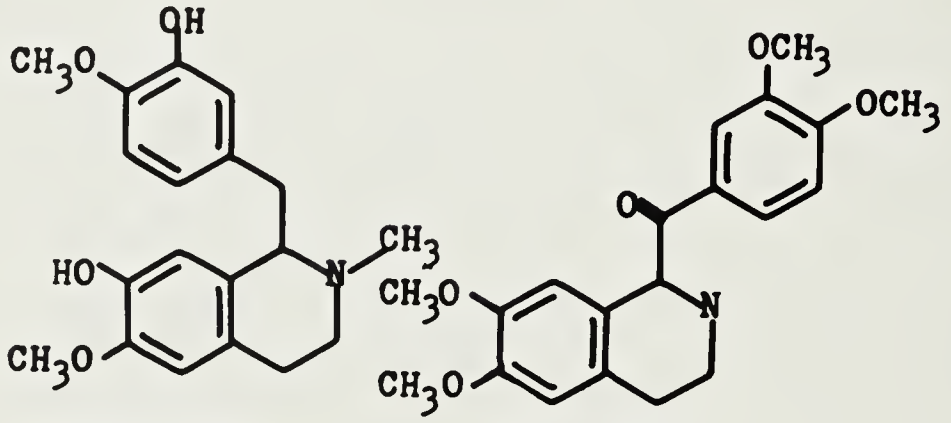
MORPHINE



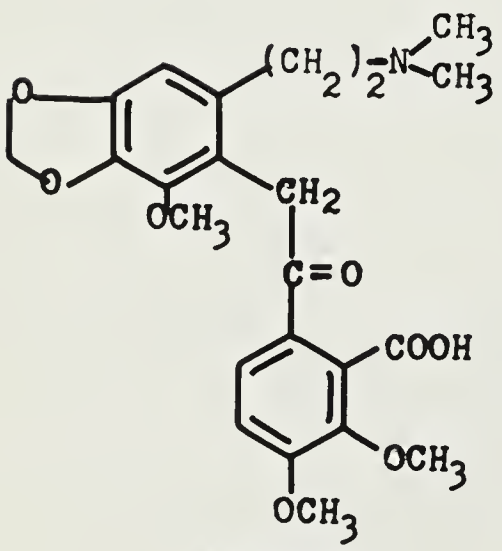
CODEINE



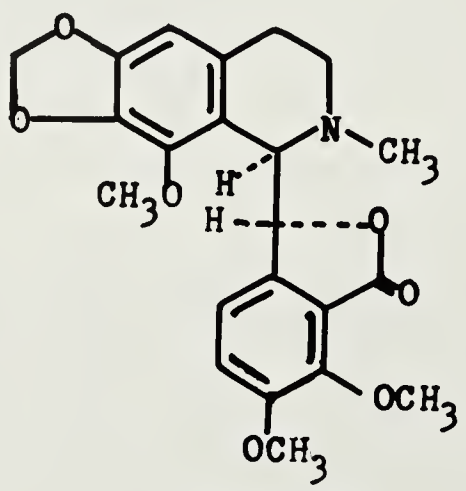
THEBAINE



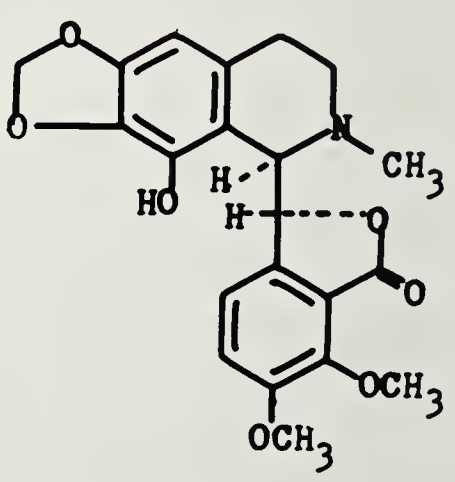
RETICULINE PAPAVERINE



NARCEINE



NARCOTINE
NOSCAPINE



NARCOTOLINE

FIGURE 3. Chemical structure of alkaloids present in seedlings of poppy (*Papaver somniferum* L.).

3rd day group.

Seventh, 8th and 9th day seedlings contained the same compounds as reported present in the previous extracts, but in still larger amounts. This was indicated by spots more intense as well as of larger total area. The extract from 8th day seedlings had in addition to the other compounds another spot below morphine and below codeine. These spots were not seen on plates from the other extracts and their identity was not known. In another context "morphine like" and "codeine like" substances are reported (Fairbairn and El-Masry, 1968). These compounds might be of this type.

It is interesting to note that the alkaloids present in the early development of the seedling of poppy are the same as those present in the developing capsule—the period when production is at its peak. This is true not only for the major alkaloids, but also for minor ones that might be expected to vary widely during ontogeny of the plant. This might imply that the effect of environment on alkaloid production is not as great as is encountered in some of the other plants studied, and may even indicate that environmental variables such as fertilizer treatments that often merit major consideration in influencing alkaloid synthesis is of less importance where poppy alkaloids are concerned.

It is of interest further to note that Fairbairn and Kapoor (1960) who worked with the anatomy of poppy seedling, growing plant and developing capsule, found latex vessels at the stage where cotyledons expanded and became green. They did not find any in seedlings younger than this stage. They indicated the appearance of these vessels as at 8 days, although this stage of cotyledonary development was reached by the 4th day. This would imply that the synthesis of alkaloids is intimately associated with the development of the latex vessels. In contrast to certain other alkaloid producing plants where synthesis is associated with actively dividing root apical cells, it would appear that deveolping laticifers are the site of synthesis of the poppy alkaloids.

It was not possible to measure accurately the amounts of alkaloids present in the extracts that were chromatographed. Massicot (1961) reported measurement of 16 μg. of thebaine from 100 7th day seedlings. He applied the separate compounds which result in the Dragendorff-alkaloid complex to filter paper sheets separately, allowing the complex to form on the paper at the point where alkaloids were located after chromatography, thus making a far more sensitive measure than usual. Several careful attempts to repeat his method on paper and apply it to thin-layer determination were unsuccessful. Though concentrations of morphine and codeine, and the high concentration of thebaine reported by Massicot appear to be in agreement with our results, it appears strange that he did not report also the large amounts of papaverine and narcotine which were also found by the thin-layer method of separation.

Attempts were also made in this study to feed C^{14} sucrose and tyrosine to seedlings during a period of growth followed by killing, extrac-

tion and separation by TLC, and the determination of radioactivity in various constituents. Though large amounts of radioactivity from sucrose and tyrosine were fixed into tissue constituents, the amount incorporated into alkaloids was so small that this means of measurement was not considered satisfactory.

Of particular interest to workers in the area of public health is the observation of Fairbairn and El-Masry (1968) that a form of "bound" morphine is present in the seed of poppy. Though large amounts of poppy seeds are commonly used in cooked and baked foods, few references have been made to untoward pharmacological effects, and these are presumably due to latex of the fruit wall contaminating seeds in preparation. Where clean seeds were ground and exposed to vigorous acid hydrolysis or acid-pepsin digestion for several hours, codeine and several morphine-like substances were shown to be present in the seeds. These compounds are presumably bound to a protein or other large molecule and are probably not hydrolyzed by stomach acid in a short time. Widespread interest will attend further reports of this seed-alkaloid relationship.

Acknowledgments

This work was done during a Sabbatical Leave from the University of Illinois of F. A. Crane in the laboratory of J. W. Fairbairn at the School of Pharmacy, University of London, 1967.

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Manuscript received, June 13, 1969

PURIFICATION AND PROPERTIES OF UREIDOGLYCOLATASE FROM *CANDIDA UTILIS*

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ABSTRACT. — The specific activity of ureidoglycolatase in extracts of *Candida utilis* was increased about 5.4-fold by induction with uric acid and to a lesser extent with allantoin or allantoate as inducers. The enzyme was purified about 100-fold by ammonium sulfate fractionation and DEAE-cellulose chromatography. Maximum stability of the purified enzyme was near pH 7.7, the enzyme was inactivated when held at pH 7.0 and 60°C for 20 minutes and Q_{10} was 2.1. K_m was 0.5 m*M* when measured by the spectrophotometric assay method, glyoxylate was a competitive inhibitor, and allantoin and allantoate inhibited ureidoglycolatase. Mn^{++} (30-80μM) stimulated the activity of the yeast enzyme.

Valentine *et al.* (1962) demonstrated the presence of ureidoglycolatase in extracts of *Streptococcus allantoicus* and a *Pseudomonas* species when these bacteria were grown on allantoin. The enzyme from *S. allantoicus* was purified by Gaudy *et al.* (1965) and characterized by Gaudy and Wolfe (1965). Vogels (1963) studied ureidoglycolatase in *S. allantoicus* and in *Arthrobacter allantoicus* and Trijbels and Vogels (1966a,b) reported on the presence and some of the properties of this enzyme in *Pseudomonas* and *Penicillium* species; the microorganisms used for enzyme preparation were grown on allantoin in these reports. Domnas (1962) reported the presence of ureidoglycolatase in the yeasts *Candida utilis* and *Saccharomyces cerevisiae* grown on various nitrogen sources. Lee and Roush (1964) noted the presence of ureidoglycolatase in conjunction with allantoicase in these yeasts.

Choi *et al.*, (1966, 1968) studied the purification and properties of allantoicase in *C. utilis* and reported methods for the assay of yeast ureidoglycolatase. This paper is a report on the purification and properties of the ureidoglycolatase of *C. utilis* and is a continuation of our study of purine catabolism in yeasts (Lee and Roush, 1964; Choi *et al.*, 1966, 1968; Roush *et al.*, 1959). A preliminary report of this work has been presented (Choi and Roush, 1965).

MATERIALS AND METHODS

C. utilis (ATCC 9950) was grown as reported previously (Roush *et al.*, 1959). Sodium ureidoglycolate was prepared by the method of Valentine and Wolfe (1961). Tris buffers were adjusted to the desired pH with acetic acid; buffer molarities refer to the concentration of Tris. Other chemicals were from sources given in previous papers (Lee and Roush, 1964; Choi *et al.*, 1966, 1968).

The methods of enzyme induction and measurement of uric acid, al-

lantoin and allantoate uptake were reported previously (Choi *et al.*, 1968; Roush *et al.*, 1959). Enzyme extracts were obtained from *C. utilis* by shaking 10 g of induced yeast suspended in 30 ml of 0.1 *M* Tris acetate (pH 7.0) with glass beads (Lee and Roush, 1964) for 3.5 hours.

Ureidoglycolatase activities were measured either by the spectrophotometric method of Choi *et al.*, (1966), which depends upon the formation of glyoxylate phenylhydrazone, or by the microdiffusion assay of these authors, which depends upon the determination of urea with the aid of urease. Specific activities are given in units of μmoles/min/mg of protein.

Results

Induction and preparation of ureidoglycolatase

The results in Table I show that the specific activity of ureidoglycolatase in the yeast extracts was increased about 1.6-fold with allantoin and allantoate as inducers and about 5.4 fold with uric acid as the inducer, consequently, uric acid was used to induce ureidoglycolatase for the purpose of purification and characterization.

All steps of the purification process were carried out at 4°C and ammonium sulfate solutions were equilibrated for 30 minutes before centrifugation to remove precipitates. The crude enzyme extracts were concentrated by fractionation between 0.5 and 0.65 saturation with ammonium sulfate, the precipitate was dissolved in 0.1 *M* Tris acetate (pH 7.0) and the resulting solution was dialyzed against several changes of a large volume of 5 m*M* Tris acetate (pH 7.0) until the diffusate gave a negative Nessler's test for ammonium ion. This fractionation usually resulted in a several-fold increase in specific activity with a recovery of about 50% of the enzyme units.

Table I. Induction of Ureidoglycolatase in *Candida utilis*. Each inducer was used in a concentration of 0.1 mg/ml. Ureidoglycolatase activities were measured at pH 7.0 by the spectrophotometric method.

Inducer	Induction Time	Protein in the Extract	Specific Activity
	(hours)	*(mg/ml)*	*(100·μmoles/min/mg of protein)*
None	0	6.6	0.35
Uric acid	5	7.4	1.2
Uric acid	7	8.0	1.7
Uric acid	10	8.0	1.9
Allantoin	1	9.9	0.23
Allantoin	3	5.6	0.57
Allantoin	5	6.6	0.48
Allantoate	1	5.9	0.45
Allantoate	3	6.9	0.54
Allantoate	5	7.6	0.54

Figure 1 shows the results of chromatography of ureidoglycolatase on DEAE-cellulose. In this experiment, the most active sample has a specific activity 96-fold greater than that of the enzyme placed on the column and the total recovery of enzyme units was 150%. The fractions eluted from DEAE-cellulose with the higher specific activities were used in studying the properties of the enzyme.

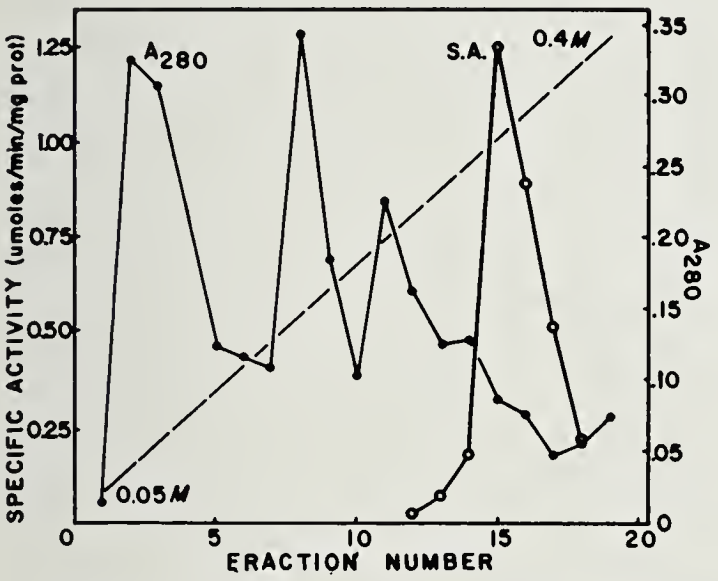

FIGURE 1. Chromatography of ureidoglycolatase on DEAE-cellulose. The DEAE-cellulose column (1.6 x 25 cm) was equilibrated with 0.05 *M* Tris acetate (pH 7.0) and ureidoglycolatase (34 mg of protein in 3.5 ml, specific activity of 0.035 unit) was added to the column. The column was eluded with a linear gradient of Tris acetate (pH 7.0) between 0.05 *M* and 0.4 *M* at the rate of 30 ml/hour and 7 ml fractions were collected.

Properties of ureidoglycolatase

Figure 2 shows that maximum stability of the purified enzyme was near pH 7.7 and Figure 3 shows that ureidoglycolatase was completely inactivated upon being held at 60°C for 20 minutes. Figure 4 is an Arrhenius plot of the effect of temperature on the reaction rate. An experimental activation energy of 12,000 cal/mole was calculated from the graph, Q_{10} between 11° and 21° was 2.1, and inactivation of the enzyme became evident at 40°C. A K_m value of 0.5 m*M* was obtained from Figure 5; however, K_m values estimated by studying the effect of substrate concentration with the microdiffusion assay were near 10 m*M* (see Figure 6, for example).

Uric acid (2 m*M*), urea (6.7 m*M*), L-arginine (3.3 m*M*) and ammonium sulfate (0.1 *M*) did not inhibit ureidoglycolatase in the indicated concentrations when the spectrophotometric assay system was used. Potassium allantoate (3.3 m*M*) inhibited 23% and allantoin (6.7 m*M*) inhibited 23% with this assay sys-

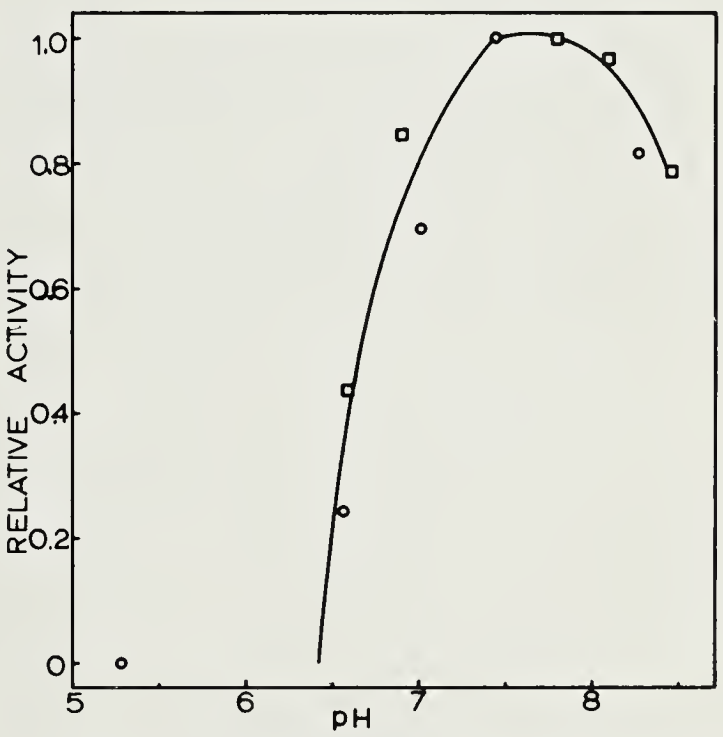

FIGURE 2. pH-stability curve for the ureidoglycolatase of *C. utilis*. Purified enzyme, eluted from a DEAE-cellulose column, was dialyzed for 4.5 hours against 2 changes of 5 m*M* Tris acetate (pH 7.0) and 0.5 ml portions of the dialyzed enzyme were mixed with 0.5 ml portions of Tris acetate buffers. These were placed in a 40°C water bath for 20 minutes, cooled in an ice bath, and 0.1 ml of each was assayed by the spectrophotometric method. The pH of each heated enzyme was measured with the glass electrode. The results of two experiments are combined in the figure.

tem. The results of glyoxylate inhibition experiments obtained by the microdiffusion assay system and plotted by the method of Dixon (1953) in Figure 6 show that glyoxylate was a competitive inhibitor with K_i = 4 m*M*.

We have found that manganous and zinc ions in the concentration range from 30 to 80 μM stimulate the activity of the purified ureidoglycolatase. The rate was occasionally doubled with manganous ion and smaller effects were observed with zinc ion. We have been unable to demonstrate an absolute requirement for a divalent cation; attempts to obtain an inactive enzyme which could be reactivated with manganous or zinc ions were unsuccessful.

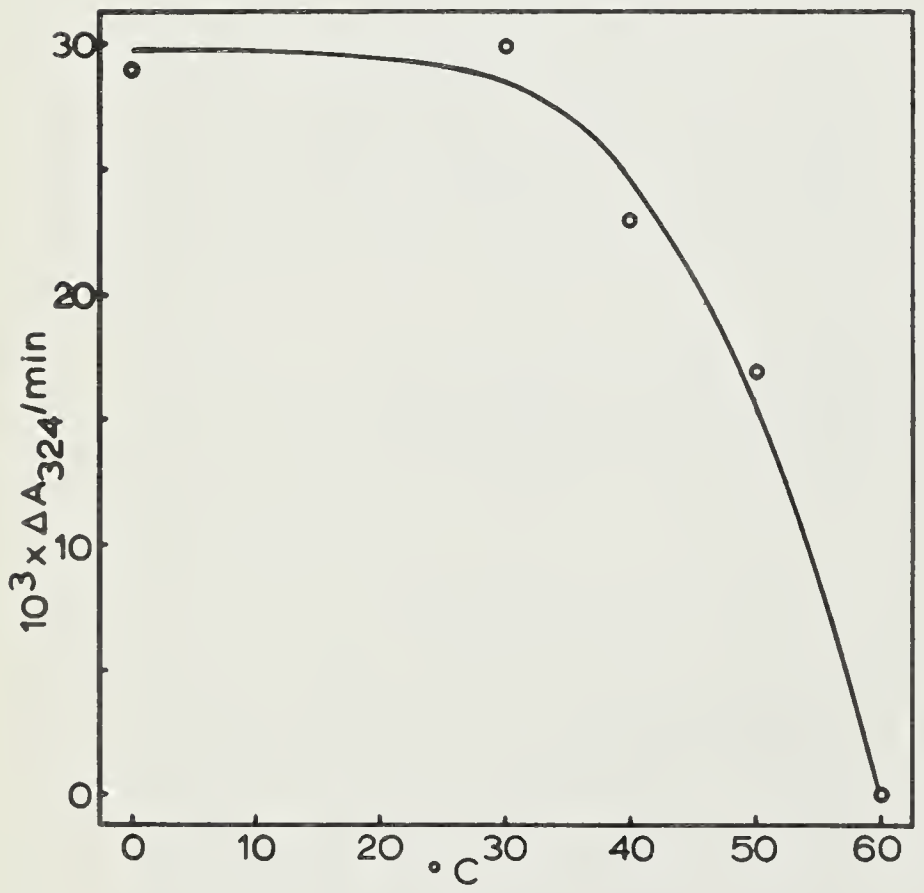

FIGURE 3. Thermal inactivation of ureidoglycolatase. Purified enzyme was held at the indicated temperature for 20 minutes, placed in an ice bath and assayed for residual ureidoglycolatase activity by the spectrophotometric method; 13 μg of protein was present in the assay solution.

DISCUSSION

The results of various workers indicate that ureidoglycolatase is required for the metabolism of allantoin or allantoate as carbon or nitrogen sources and that the enzyme is inducible in microorganisms. Gaudy and Wolfe (1965) reported that ureidoglycolatase was present in allantoin-grown but not in glucose-grown cells. Domnas (1962) found ureidoglycolatase in *C. utilis* grown with ammonium sulfate as the nitrogen source and the specific activity of ureidoglycolatase in extracts was increased 21-fold by growth on allantoin; growth conditions were not

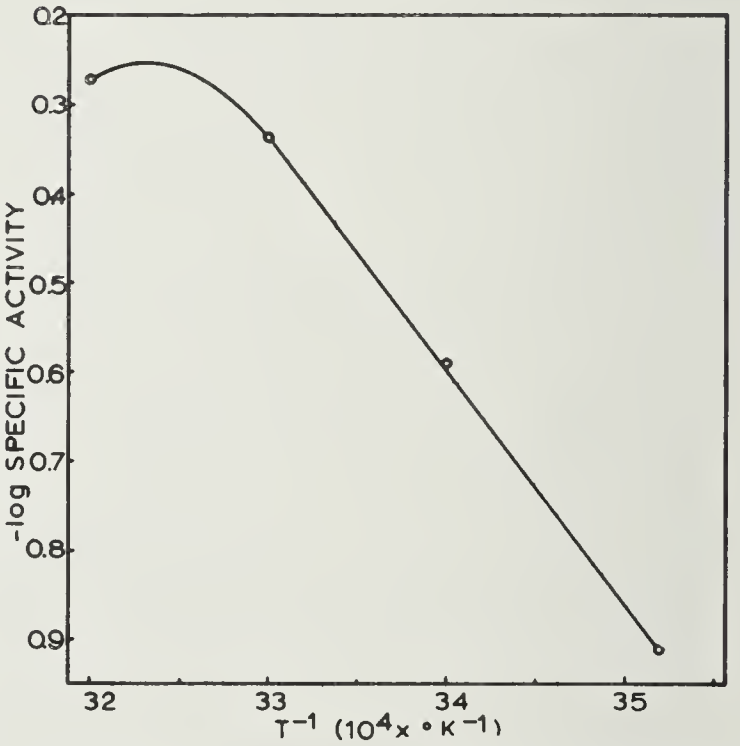

FIGURE 4. Variation of ureidoglycolatase activity with temperature. Purified enzyme was assayed by the spectrophotometric method over the indicated temperature range. Water from a constant temperature bath was circulated through the thermospacers of the spectrophotometer and each reaction solution was equilibrated to constant temperature before starting the reaction. The temperature was measured at the end of the reaction by placing a thermometer previously equilibrated at the temperature of the bath in the cuvette. The logarithm of the measured specific activity is plotted against the reciprocal of the absolute temperature.

defined for these experiments. Our results are in qualitative agreement but we find much lower specific activities and only a slight increase in specific activity upon incubation in allantoin as the sole nitrogen source under our conditions. Uric acid was the best inducer, possibly because it accumulates in the vacuole in crystalline form (Roush, 1961) and provides a constant source of purine catabolites for induction over a prolonged period of time. The results of Choi *et al.* (1968) taken in conjunction with the present results support the conclusion of Lee and Roush (1964) that allantoicase was induced in *C. utilis* by purine metabolites and was not present in detectable amounts in *C. utilis* grown on ammonium sulfate; ureidoglycolatase is present in non-induced cells and did not prevent the detection of allantoicase in the assay procedure of Lee and Roush (1964).

The success in purification of ureidoglycolatase by chromatography on DEAE-cellulose depended upon the strong adsorption of the enzyme by DEAE-cellulose in 0.05 *M* Tris buffer; much of the protein and nucleic acid are not adsorbed strongly under these conditions and appear in the eluate at lower ionic strengths than provided by the 0.3 *M* Tris buffer required for elution of the ureidoglycolatase. The high recovery of activity may be due to the removal of inhibitors during chromatography. Possible inhibitors include divalent heavy metal ions (Gaudy and Wolfe, 1965) or proteins and nucleic acids. The latter classes of compounds have structural similarities to the substrate.

Our K_m value of 0.5 m*M*, obtained by the spectrophotometric assay, is much smaller than the value of 92 m*M* reported by Trijbels and Vogels (1966a) for the enzyme from *Pseudomonas acidovorans* or the value of 33 m*M* reported by Gaudy and

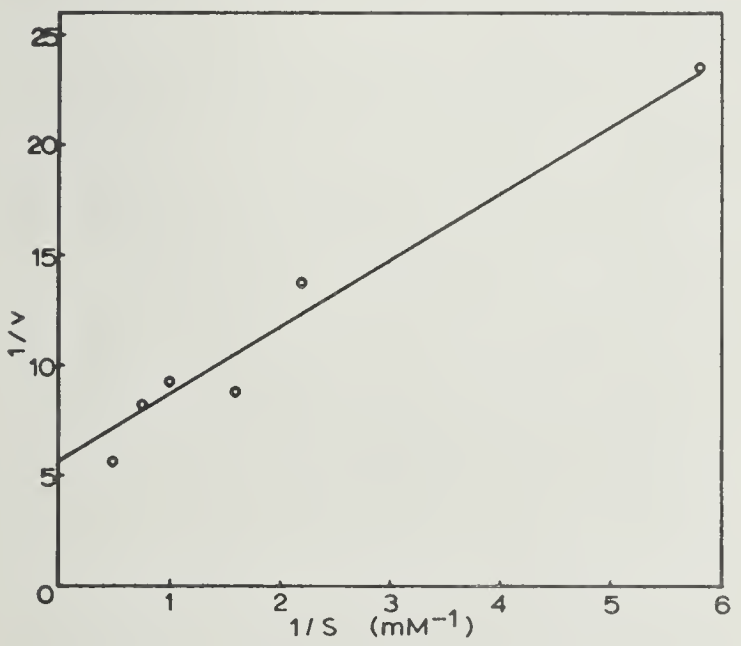

FIGURE 5. The effect of substrate concentration on ureidoglycolatase activity. Purified enzyme (specific activity = 0.52 unit) was assayed by the spectrophotometric method. The units of v are μmoles/min/3 ml and (0.1) $(1/v)$ is the ordinate in the reciprocal plot. The line was drawn by the method of least squares.

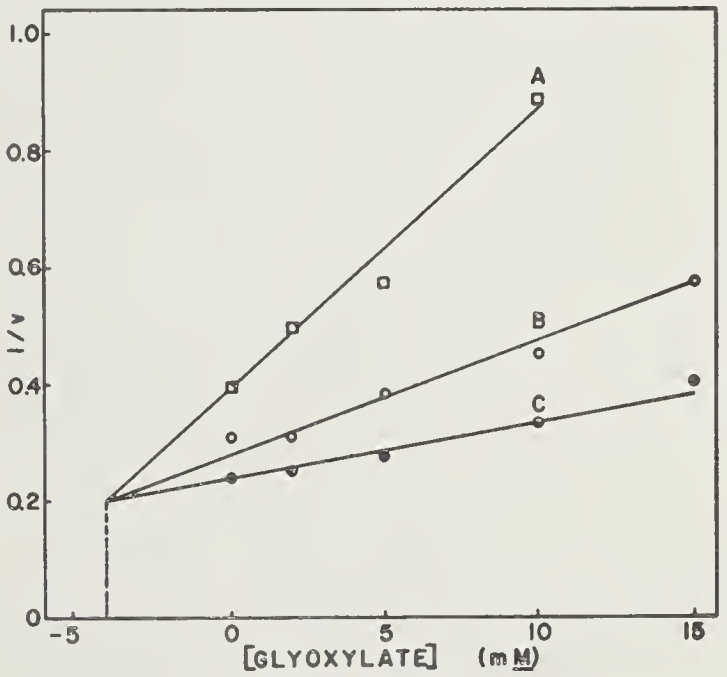

FIGURE 6. The inhibition of ureidoglycolatase by sodium glyoxylate. The activities were measured at pH 7.0 and 30°C for 30 minutes by the microdiffusion assay in a volume of 2 ml containing 69 μg of purified ureidoglycolatase and 0.8 mg of urease. Ureidoglycolate concentrations:
A, 5.25 m*M*; B, 9.50 m*M*; C, 15.90 m*M*.

Wolfe (1965) for the enzyme from *S. allantoicus*. The K_m value of 10 m*M* which we estimated from microdiffusion assay data is more nearly of the order of magnitude of the values given by the other workers. The difference between the K_m values obtained by the two assay systems might be due to phenylhydrazine acting as a direct acceptor of the glyoxylate from an enzyme-substrate complex in the spectrophotometric assay system.

Glyoxylate was a competitive inhibitor of yeast ureidoglycolatase which indicates that the glyoxylate moiety of ureidoglycolate may be involved in the formation of the enzyme-substrate complex. Urea was not inhibitory, in agreement with the results of Gaudy and Wolfe (1965), but these authors found that 1 m*M* glyoxylate did not inhibit their enzyme, in contrast to our results with the yeast enzyme.

Gaudy *et al.* (1965) recovered 174% of their enzyme activity in a purification step which employed 20 m*M* Mn^{++} and Gaudy and Wolfe (1965) found that 1 m*M* Mn^{++} stimulated the activity of their enzyme to 131% of the control value. Vogels (1961) and Trijbels and Vogels (1966a) have reported stimulations of ureidoglycolatase activity by 0.16 m*M* and by 0.77 m*M* Mn^{++} respectively. We have found maximum stimulation of the yeast ureidoglycolatase by 60 μM Mn^{++} and no effect or inhibition at higher concentrations. More recent results obtained in this laboratory (N. Spalek and A.H. Roush, unpublished observations) show that Mn^{++} in concentrations of 1 m*M* or higher catalyzes the cleavage of ureidoglycolate in the spectrophotometric assay system and therefore we conclude that caution must be exercised in attributing stimulation of ureidoglycolatase activity by higher concentrations of Mn^{++} to an effect on the enzyme. Some of the observed results may be due to direct Mn^{++} catalysis of ureidoglycolate cleavage.

Acknowledgment

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DIELECTRIC CONSTANTS AND ASSOCIATION IN DILUTE ETHANOL SOLUTIONS IN CARBON TETRACHLORIDE

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ABSTRACT. — Dielectric constant versus concentration data have been collected for solutions of ethanol in carbon tetrachloride over the concentration range of 0.015 to 0.085 *M*, and the data are presented as an example of the indication of the association behavior in such systems. The resulting curves have been statistically analyzed by computer techniques.

In recent years there have been a number of studies on dielectric properties of solutions of materials which may involve hydrogen bonding. However, most of these studies on alcohols have dealt with solutions varying in alcohol concentration over the entire range of zero to one mole fraction, with few if any measurements reported for dilute solutions containing alcohols in concentrations of less than about 0.10 *M* (Gold and Perrine, 1967A; Gold and Perrine, 1967B; Malecki, 1962; Malecki, 1965; Piekara, 1962). Rodebush, *et al.*, have shown that the total polarization curves for solutions of some alcohols in carbon tetrachloride show a decrease in slope at concentrations where association is considerable (Rodebush, Eddy, and Eubank, 1940). Spectroscopic studies have shown that alcohols are extensively self-associated even at relatively low concentrations in inert solvents (Fletcher and Heller, 1967A; Hammaker, *et al.*, 1968; Fletcher and Heller, 1967B; Van Ness, *et al.*, 1967). Similarly, at intermediate and high concentrations, the alcohols are extensively associated in higher aggregates. Therefore, most of the measurements on dielectric properties of alcohol solutions have been made on solutions in which the alcohols are not involved primarily in a monomer-dimer equilibrium. It has been shown that for the case of some simple alcohols in nonpolar solvents the slope of the dielectric constant versus concentration curve exhibits a less rapid increase in the concentration range dominated by monomer-dimer equilibrium than on either side of this range (Smith, 1955, pp. 303-306).

This report presents, as a specific instance in detail of the above, dielectric constants for solutions of ethanol in carbon tetrachloride at concentrations less than 0.1 *M* and their apparent indication of variations in the predominant equilibrium.

EXPERIMENTAL

Materials. The CCl_4 used as a solvent was washed several times al-

ternately with alcoholic KOH, water and concentrated H_2SO_4 until the washings were colorless. The purified material was distilled from $CaCl_2$ and stored in ground-glass stoppered containers, and all subsequent operations were carried out with the exclusion of moisture. The purified material gave no proton resonance spectrum and showed no absorption in the infrared spectrum in the region where O-H stretching bands are found.

Ethanol was refluxed with metallic sodium or magnesium and vacuum distilled. It was stored in glass stoppered containers kept in a desiccator. The CCl_4 solutions were stored in the dark and were prepared with freshly purified CCl_4 approximately weekly. Standards used for instrument calibration in determining dielectric constants were cyclohexane and chlorobenzene. These materials were freshly distilled spectral grade chemicals.

Dielectric Constant Measurements. Dielectric constant measurements were made using a Sargent Model V Oscillometer. Conversions of scale readings to cell constants and to dielectric constants were programmed. All measurements were made at 25 ± 1°C. Individual dielectric constants are estimated to be accurate to within about ±0.003. The dielectric constant data, as a function of concentration, were examined by a computerized polynomial regression technique.

Results and Discussion

The dielectric constants obtained for the dilute ethanol solutions are shown in Table I. A plot of the average values given in Table I shows that the relationship of concentration to dielectric constant is not linear but rather has a region of lower slope between about 0.04 and 0.07 *M*. This same behavior was observed for several sets of ethanol solutions other than those for which measurements are given in Table I.

Table I. Dielectric Constants of Dilute Ethanol Solutions in Carbon Tetrachloride.

Concentration, moles/liter	Dielectric Constant			
	Series I	Series II	Series III	Average
0.01505	2.225	2.230	2.230	2.228
0.02096	2.228	2.234	2.230	2.231
0.02989	2.236	2.235	2.236	2.236
0.03694	2.237	.....	2.241	2.239
0.04297	2.237	2.245	2.243	2.242
0.04521	2.241	2.244	.....	2.243
0.05231	2.238	2.246	2.246	2.243
0.05552	2.241	2.244	2.245	2.243
0.05804	2.242	2.246	2.244	2.244
0.06627	2.245	2.246	.....	2.246
0.07352	2.252	2.250	2.249	2.250
0.07843	2.250	2.254	2.252	2.252
0.08547	2.258	2.259	2.261	2.259

Figure 1 shows the non-linear relationship of the average dielectric constants to concentrations of ethanol solutions. The specific nature of the non-linearity of these curves is also illustrated by the fact that the best fit of the curves as indicated by the computerized analysis of variance of the regression results was a cubic equation in all cases.

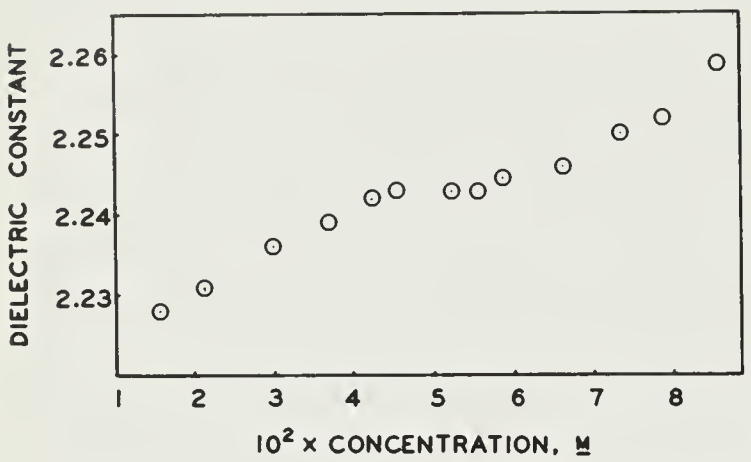

FIGURE 1. The Non-linear Relationship Between Dielectric Constant and Ethanol Concentration in Carbon Tetrachloride.

The shape of the curve in Figure 1, which is typical of all the series of ethanol solutions studied, is indicative of the self-association behavior. The curve has a decrease in slope beginning at about 0.04 *M*. This is interpreted as being due to the fact that at about this concentration the alcohol begins to exist to a sizable extent in the form of dimers which results in a partial cancellation of permanent dipole moment contributions to the dielectric constant. This is in accord with evidence from spectral studies. It is at about this concentration that peaks appear which are attributed to alcohol dimers (Hopkins, 1967). Going to higher concentrations produces larger aggregates which have structures in which dipole moments do not tend to cancel. The dielectric constant then rises faster as is seen in Figure 1, the slope increasing from concentrations of about 0.07 *M* upward.

It thus appears that equilibrium among hydrogen-bonded species gives rise to a significant effect on the dielectric constants of alcohol-carbon tetrachloride solutions in a range of concentration not usually examined in such detail. These effects occur at concentrations similar to those where monomer-dimer and monomer-dimer-multimer equilibria have been shown to predominate and have been studied by infrared spectroscopy.

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NOTES

ROBERT KENNICOTT, AN EARLY PROFESSIONAL NATURALIST IN ILLINOIS

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ABSTRACT. — Robert Kennicott, active in the 1850's and 1860's, was among the few professional naturalists in Illinois. He achieved this status at a time when most naturalists pursued their study as an avocation. The information about Kennicott is primarily from the Kennicott-Baird correspondence in the Smithsonian Institution.

It is well-known that many scientists have embarked on their careers when they were boys. Today potential field biologists begin as bird watchers, or as assistants in the high school lab as collectors of pond water and caretakers of aquaria. They are eager entrants in science fairs, and often they are Boy Scouts who go in for long canoe trips and wilderness camping. In the nineteenth century, as boys, future naturalists were collectors of bird's eggs, butterflies, fossils, snakes, and other natural objects, or they hunted birds and small animals that were so commonly found in rural and small-town America. I have asked my natural scientist friends when they became interested. With one exception they said that it was at the age of ten or twelve or fifteen. The exception is a man whose interest was not aroused until he was well along in college, and he became a parasitologist—a closet scientist, not a field biologist.

My thesis is demonstrated by the life of Robert Kennicott, an Illinois naturalist of the middle nineteenth century. He was a protégé of Spencer F. Baird, the assistant secretary of the Smithsonian Institution. There was an extensive correspondence between the two. The Smithsonian very kindly provided me with microfilms of the correspondence, which consists of more than a thousand items. Fortunately I was able to get the microfilms enlarged and Xeroxed so that reading Baird's somewhat crabbed writing, and struggling with Kennicott's unconventional spelling was possible.

Robert Kennicott was born in 1835 in New Orleans. His father was John Kennicott, a physician. I have not so far been able to trace the antecedents of John Kennicott, and I do not know why he was in New Orleans, but shortly after the birth of Robert, the family moved to Illinois, settling on a farm about fifteen miles north of the Chicago Loop, near a brother who had already established himself there.

Dr. Kennicott engaged in practice and drove his horse and buggy all over the muddy (or dusty) trails of the prairie to care for his patients. He was also a farmer and horticulturist, eventually devoting all of his time to the business of raising shrubs, fruit trees, and shade trees, selling them throughout the region. The Kennicott home itself was surrounded by trees, and was called The Grove. It was one of the many small stands of trees that were to be found at intervals on the flat, grass-covered land.

Dr. Kennicott was a believer in education, but not an especially strong supporter of schools. He and his wife taught the rudiments to the children, and they were seldom sent to school. The Doctor thought that children could learn more from being in contact with nature and by engaging in manual labor.

Robert Kennicott was not a very strong boy physically, and bouts of not clearly defined illnesses seemed to occur when he did go to school. For this reason, and because he did not have much faith in formal schooling, Dr. Kennicott let his son stay home, and

encouraged him to be outdoors as much as possible. Robert did his share of the work, especially during the busy fall and spring planting seasons. At the same time he began to collect insects and bird's eggs, and to capture mice, squirrels, snakes, and frogs. Many of these animals were put in cages so that their habits could be closely observed. Kennicott's companion on his rambles was often a half-breed Indian who hunted birds, and ran a trapline in the winter.

At The Grove were also domestic animals, and the wild birds were fed and their nesting places were carefully protected. One strange pet was a four-foot tall Sandhill crane. It had the run of the place, followed the children around, and was always present when plowing and digging were going on because it relished the insect larvae, mice, shrews, and moles that were turned up.

As time went on, Dr. Kennicott turned more and more to his horticultural interests, and participated in the affairs of state and regional associations. Through these contacts he came to know Dr. Jared P. Kirtland, a leading naturalist and practicing physician of Cleveland. Dr. Kennicott told Kirtland about Robert, and the latter was put in touch with Professor Baird at the Smithsonian. Robert was also invited to spend a half-year in Dr. Kirtland's home on the shore of Lake Erie. Dr. Kirtland tutored the young man, and taught him how to identify and classify natural history objects. Robert was also introduced to the standard works on natural history that were in Dr. Kirtland's library.

Professor Baird's special duty at the Smithsonian was to direct the natural history museum. To get specimens, Baird made contacts with natural history enthusiasts in many parts of the country. The Professor was a kindly man, very patient and deliberate, and he encouraged his correspondents in their collecting activities.

Some of the younger men became practically members of the Baird family, because they were brought to Washington to work in the museum at the identification and classification of the flood of material that came in. The men were invited to the Baird home, and Mrs. Baird and her daughter took an interest in their welfare.

A close relationship developed between Kennicott and the Professor. Throughout his life Robert wrote to Baird about all of his problems, and Baird answered fully, giving his advice when he thought it desirable, but refraining when he thought Robert should make up his own mind. But more importantly, Baird, in his letters to Robert, gave practical instruction about what to collect, how to preserve specimens, and how to identify and classify them.

As Robert approached his nineteenth birthday, he was troubled by the necessity to decide on a career so that he would be financially independent of his father. At The Grove Robert was doing farm and nursery work, but spending most of his time exploring the countryside and collecting specimens for his own cabinet and for the Smithsonian museum. To the latter he sent off, usually by railway express, live animals and snakes in crates and baskets, fish and frogs in alcohol, insects mounted on boards, and bird skins and animal pelts packed in boxes. Kennicott also began to keep a written record of his observations of the habits of these creatures as he observed them in the field. Although Baird encouraged these activities, he kept always before Robert the idea that natural history should be an avocation, and he urged the young man to complete his schooling and prepare himself for entrance to medical school in Chicago.

On the other hand, Robert's father was continually suggesting that his son should pursue his natural history interests. He introduced Robert to another friend, Dr. Philo Hoy of Beloit, Wisconsin, a man who spent as much time at natural history as he did at medicine. He was nationally known as a specialist in bird identification and classification. At Dr. Hoy's invitation Robert spent a spring season at Beloit, and learned to collect and skin birds.

It was through the influence of his father that Robert got his first job as a field biologist. In 1854 he was employed by the Illinois Central Railroad to survey the natural history along the right-of-way from Chicago to Cairo. Robert received no salary, but his transportation was free, and Baird supplied a small sum toward his expenses in return for the specimens that Robert sent to the Smithsonian. He accumulated sufficient material for Baird to ask him to spend the winter in Washington arranging the specimens. Dr. Kennicott also got his son to try his hand at writing, and several of Rob-

ert's articles were printed in *The Prairie Farmer*, an agricultural and horticultural paper published in Chicago. Dr. Kennicott was also active in the affairs of the Illinois Agricultural Association and other groups that were trying to get the state legislature to organize and pay for a comprehensive natural history survey. Dr. Kennicott wanted his son to be named the head of the survey, but the whole project fell through when the legislature balked at the expense. A private survey was organized by the Illinois Natural History Society, but Robert was not named director. He and his father felt the survey was not very good, and that Robert would have done better with it.

In the meantime Baird saw that Robert was not going to give up his attempts at a professional career in natural history, and when he read Robert's articles for *The Prairie Farmer*, he persuaded the United States Patent Office, which published an annual volume of material of interest to farmers, to pay Robert for a work on wild animals that were "injurious and beneficial" to agriculturists. It was generally believed in the 1850's that most wild animals were "varmints," and that they ruined crops and should be exterminated. Robert, in common with most informed men, did not believe that squirrels, skunks, and other small animals were wholly injurious. He put his point of view succinctly when he wrote, "Before waging war on any animal, let us study its habits, and look well to the consequences which would follow its extermination." Robert's work occupied more than a hundred pages in the Patent Office reports. It is still pleasurable to read, because Kennicott's remarks were drawn from personal observation of the animals in both captivity and the wild state. His style of writing was lively and anecdotal, and he refrained from using technical terms. These articles were also printed in the reports of the Illinois Agricultural Association.

By this time Robert had a clear hope of supporting himself as a naturalist, and although he did try to go to medical school, he dropped out because he said that his eyes went bad on him. As a matter of fact he far more enjoyed doing the writing for the Patent Office publication, and he quickly recovered his health after he withdrew from medical school and returned to The Grove to work on his articles.

Through his association with the doctors of Chicago his abilities as a naturalist became known, and he was employed by Northwestern University, just being organized, to provide a natural history museum, a job for which he was paid. At the same time Robert was also cooperating with the doctors and other men who had organized the Chicago Academy of Sciences. For both organizations Robert went on field trips, one of which was to the Lake Superior region. Through connections made there, he later went on an extensive collecting trip through northern Canada in the territory where the Hudson's Bay Company operated. His well-written journal of his experiences is a fascinating natural history and adventure chronicle that deserves to be better known.

On these trips he was supported not only by Northwestern and the Chicago Academy, but by the Smithsonian Institution. He had also become the salaried director of the Academy's museum and hoped to make it a "Smithsonian of the West." By the time he was twenty-five years old, Kennicott was a self-supporting professional naturalist. (This is about the age when today's scientists get their Ph. D.'s and start on their careers.) Kennicott's greatest success as a field biologist was in Canada, and through the reputation he made there he was recommended by Baird to direct the survey of Alaska that was undertaken by the Western Union Telegraph Company in 1865. The purpose was to build a line up the west coast of North America to Alaska, over the Bering Straits, and across Siberia to Europe. His salary was $2400 a year, and he was also given stock in the enterprise. That it failed is another story. Certainly Kennicott's part in the survey, and the collections of natural history objects he made established him as one of the leading explorers of the day.

But perhaps there had been bodily weakness during his youth, and the illnesses he suffered then were a part of the reason for the heart failure that killed him, at the age of thirty-one, while he was in Alaska. The reports of Kennicott's expedition describing the natural resources were widely quoted when the Senate discussed and finally ratified the treaty whereby the United States acquired Alaska from Russia in 1867—and that is another interesting story.

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THE EFFECT OF ULTRAVIOLET LIGHT ON THE GROWTH OF *HELMINTHOSPORIUM ORYZAE*

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ABSTRACT. — *Helminthosporium oryzae* was grown on potato-dextrose agar and in potato-dextrose broth under near ultraviolet light. Increased growth of the fungus was noted with both media after the fungus had been exposed to near ultraviolet radiation. The increased growth rate was attributed to either a nuclear and cell division delay in the fungus caused by the radiation, a leakage of substances from killed cells, or the effect of near ultraviolet light on the medium.

Most fungal investigations have dealt with the effects of far ultraviolet light (1900-3000 Å) on the survival of spores, colony growth rates, and induced mutations. The majority of radiation studies have employed wavelength in the spectral range of about 2600 Å.

Relatively little work has been conducted on fungi with near ultraviolet light (3000-4000 Å). Leach (1961) and Honda (1968) reported on near ultraviolet light and how it affected the sporulation of *Helminthosporium oryzae* V. Breda de Haan. Leach (1961) stated that continuous exposure to near ultraviolet light caused an increased growth rate of the fungus in liquid media.

The goal of the present study was to examine the effect of near ultraviolet light on the hyphal growth of *H. oryzae*.

METHODS AND MATERIALS

An isolate of Leach's (1961) *H. oryzae* material was obtained from Dr. Yuichi Honda of Tohoku University, Sendai, Japan. All of the cultures used in the present study were maintained on 2% potato-dextrose agar (PDA) at 21°C ± 1°C with an initial pH of 5.7.

The inoculation procedures were identical to those employed by Leach (1961). Agar discs 3 mm-in-diameter were cut with a sterilized cork borer from the periphery of a mature colony growing on PDA. The inoculum plug was placed face down in the center of a sterile 9 cm plastic petri dish that contained 25 ml of PDA or in Pyrex glass wide-mouth bottles that contained 50 ml of 2% potato-dextrose broth (PDB). Liquid and solid media cultures were maintained in the dark until the fungal colonies had attained a growth size of 0.75 cm-in-diameter. Cultures were irradiated 16 cm from the light source on a simple shaker reciprocating through a distance of ¼ of an inch at 85 times per minute. Near ultraviolet light exposure was obtained with four 20-watt GE Black Light lamps (BLB) that had 97% of the radiation between 3000-4000 Å. All cultures were returned to the dark after irradiation. Control cultures remained in the dark at all times. Five replicates of each application were made for all experiments.

Fungal growth on solid media was determined by radial colony diameter measurements in centimeters after six days. Liquid cultures were filtered through pre-weighed filter papers after the six day irradiation period. The filter papers were dried for 48 hrs at 100 C and then re-weighed for fungal dry weight determinations.

RESULTS

Fungal cultures exposed to BLB for six days on PDA showed a decreased amount of radial growth when compared to controls. The growth of similar cultures maintained in the dark after radiation exposure surpassed that exhibited by controls after four days of maintenance. The PDB cultures exposed to BLB had dry weight values that in two instances surpassed those of the controls.

DISCUSSION

The amount of increased growth in PDB cultures exposed to BLB was lower than that reported by Leach. A significant increase in fungal growth was

noted on experimental plates after their removal from the continuous BLB exposure. The increased growth was attributed to either: (1) a nuclear or cell division delay in the fungus induced by the radiation, (2) the leakage of growth promoting substances from cells killed by near ultraviolet light radiation that later caused an increased growth rate, or (3) the effect of near ultraviolet light on the medium.

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CHECK LIST OF THE MOSQUITOES IN JOHNSON AND MASSAC COUNTIES, ILLINOIS

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ABSTRACT. — Natural swamp areas in Southern Illinois (Massac-Johnson Counties) have been study areas for Arbovirus investigations since 1963. The Illinois History Survey records are listed in addition to the mosquito collections recorded by CZR. Relative abundance of each species is indicated.

The swampy areas of Mermet Conservation Area (Massac County) and Grantsburg, (Johnson County) have been among the sites utilized for arthropod borne virus field studies conducted in the Ohio-Mississippi River Basin by the Center for Zoonoses Research, University of Illinois.

Mosquito collection records of the Illinois Natural History Survey date back to August 11, 1898, with two recordings. Later, the Natural History Survey conducted a mosquito survey in the early 1940's (Ross, 1947). The Center for Zoonoses Research initiated continuing field studies in the area in the summer of 1963. Two new state records were obtained with the collection of *Aedes infirmatus* (Hayes, 1965) and *Culiseta melanura* (Siverly, 1966). In addition to the collections of mosquitoes, birds and small mammals were also captured, bled, tagged and released. A variety of collecting techniques have been employed in mosquito collections and the St. Louis encephalitis virus isolations from this area are reported elsewhere (Kokernot, et al, 1969). The principal means of collecting mosquitoes for arbovirus isolations were the CDC miniature light trap (Sudia, 1962), with and without dry ice; human biting captures and aspiration from diurnal resting sites.

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Relative Abundance Key
I. Common
II. Frequent
III. Infrequent
IV. Rare
V. Very Rare

TABLE 1. Mosquito collection records for Johnson-Massac Counties.

Species	Date of Capture by Zoonoses Center *by Natural History Survey	Locality	Capture Method	Relative Abundance
Aedes atlanticus Dyar & Knab	August 25, 1967	Grantsburg, Johnson County	Biting (Human)	Infrequent
Aedes aurifer (Coquilett)	June 9, 1964	Mermet, Massac County	Biting (Human)	Frequent
Aedes canadensis (Theobald)	May 10, 1964 *April 17, 1941	Mermet, Massac County Grantsburg, Johnson County	Biting (Human) Larvae	Common
Aedes dupreei (Coquilett)	June 17, 1964	Mermet, Massac County	Light Trap	Very Rare
Aedes fulvus pallens Ross	June 10, 1965	Mermet, Massac County	Biting (Human)	Rare
Aedes grossbecki Dyar & Knab	April 29, 1964	Mermet, Massac County	Biting (Human)	Frequent
Aedes infirmatus Dyar & Knab	May 24, 1964	Mermet, Massac County	Biting (Human)	Very Rare
Aedes sticticus (Meigen)	April 29, 1964 *May 15, 1941	Mermet, Massac County Karnak, Johnson County	Biting (Human)	Common
Aedes thibaulti Dyar & Knab	June 9, 1964	Mermet, Massac County	Biting (Human)	Frequent
Aedes triseriatus (Say)	June 30, 1964	Mermet, Massac County	Biting (Human)	Common
Aedes trivittatus (Coquillett)	August 16, 1964	Mermet, Massac County	Biting (Human)	Infrequent
Aedes vexans (Meigen)	May 17, 1964 *May 31, 1938	Mermet, Massac County Karnak, Johnson County	Biting (Human) Larvae	Common
Anopheles barberi Coquillett	July 12, 1965	Mermet, Massac County	Larvae	Very Rare

Relative Abundance Key
I. Common
II. Frequent
III. Infrequent
IV. Rare
V. Very Rare

TABLE I.—(Continued)

Species	Date of Capture by Zoonoses Center *by Natural History Survey	Locality	Capture Method	Relative Abundance
Anopheles crucians Wiedemann	June 9, 1964	Mermet, Massac County	Light Trap	Frequent
Anopheles punctipennis (Say)	June 28, 1964	Mermet, Massac County	Light Trap	Frequent
	*April 30, 1941	Cache, Massac County	Larvae	
	*April 30, 1941	Grantsburg, Johnson County	Larvae	
Anopheles quadrimaculatus Say	June 9, 1964	Mermet, Massac County	Biting	Common
	*June 9, 1941	West Vienna, Johnson County	Larvae	
Anopheles walkeri Theobald	June 21, 1964	Mermet, Massac County	Light Trap	Frequent
Culex apicalis Adams	*April 30, 1940	Grantsburg, Johnson County	Larvae	Very Rare
Culex erraticus (Dyar & Knab)	May 12, 1964	Mermet, Massac County	Biting	Common
Culex peccator Dyar & Knab	July 16, 1965	Mermet, Massac County	Larvae	Very Rare
	*June 10, 1941	Grantsburg, Johnson County	Larvae	
Culex pipiens Linnaeus[1]	June 21, 1964	Mermet, Massac County	Biting	Infrequent
	*June 10, 1941	Vienna, Johnson County	Larvae	
Culex salinarius Coquillett	June 21, 1964	Mermet, Massac County	Biting (Mouse)	Infrequent
Culex tarsalis Coquillett	June 23, 1965	Mermet, Massac County	Light Trap	Rare
Culex territans Walker	June 28, 1964	Mermet, Massac County	Light Trap	Frequent
Culiseta inornata (Williston)	June 28, 1964	Mermet, Massac County	Light Trap	
	*April 17, 1941	Karnak, Johnson County	Larvae	Very Rare

Relative Abundance Key
I. Common
II. Frequent
III. Infrequent
IV. Rare
V. Very Rare

TABLE I.—(Concluded)

Species	Date of Capture by Zoonoses Center *by Natural History Survey	Locality	Capture Method	Relative Abundance
Culiseta melanura (Coquillett)	August 20, 1964	Mermet, Massac County	Light Trap	Rare
Mansonia perturbans (Walker)	June 9, 1964	Mermet, Massac County	Light Trap	Common
Orthopodomyia signifera (Coquillett)	July 8, 1964	Mermet, Massac County	Larvae	Rare
Psorophora ciliata (Fabricus)	June 10, 1964 *August 14, 1942	Mermet, Massac County West Vienna, Johnson County	Light Trap Biting (Human)	Frequent
Psorophora confinnis (Lynch & Arribalzaga)	June 9, 1964 *August 14, 1942 *August 14, 1942	Mermet, Massac County West Vienna, Johnson County Vienna, Johnson County	Light Trap Biting (Human) Light Trap	Infrequent
Psorophora cyanescens (Coquillett)	July 24, 1965 *August 14, 1942	Grantsburg, Johnson County West Vienna, Johnson County	Biting (Human) Biting (Human)	Infrequent
Psorophora ferox (Humboldt)	May 12, 1964 *August 11, 1898	Mermet, Massac County Grantsburg, Johnson County	Biting (Human) Larvae	Common
Psorophora horrida (Dyar & Knab)	*August 11, 1898	Grantsburg, Johnson County	Larvae	Very Rare
Psorophora howardii Coquillett	June 21, 1964	Mermet, Massac County	Biting	Infrequent
Psorophora varipes (Coquillett)	June 22, 1964	Mermet, Massac County	Biting	Common
Toxorhynchites rutilus septenrionalis (Dyar & Knab)	July 12, 1965	Mermet, Massac County	Larvae	Rare
Uranotaenia sapphirina (Osten Sacken)	June 9, 1964	Mermet, Massac County	Light Trap	Common

[1] *Culex pipiens* complex: both *culex pipiens pipiens & Culex pipiens quinquefasciatus* have been collected in Illinois.

A BRAZILIAN FREE-TAILED BAT (*TADARIDA BRASILIENSIS*) TAKEN IN NORTH-CENTRAL ILLINOIS.

HARLAN D. WALLEY
Northern Illinois University, DeKalb, Illinois 60115

ABSTRACT. — First record of the Brazilian Free-tailed bat from Illinois.

Tadarida brasiliensis mexicana is known from as far east as Lincoln, Nebraska, and Lawrence, Kansas (Hall & Kelson, 1959). *T. b. cynocephala* is known from as far north as Scioto County, Ohio (Smith & Goodpaster, 1960). Jegla & Hall (1962) found fossil remains of *T. b. cynocephala* in a guano pile within Mammoth Cave, Edmonson County, Kentucky, which shows a former wider distribution of this race than presently known.

A male, *T. brasiliensis* (NIU 769) was collected on 17 October 1969, by Mr. Svan Hansan, after flying into the greenhouse on the Northern Illinois University Campus in DeKalb, DeKalb County, Illinois. This specimen appeared to be in good physical condition, and is considered a young-of-the-year, as no signs of tooth-wear are noticable. Measurements are: total length, 84 mm; tail length, 32.5 mm; hind foot length, 8 mm; ear length, 16 mm; forearm, 41.5 mm. Skull measurements: condylobasal length, 15.9 mm; total length, 16.6 mm; zygomatic breath, 9.8 mm; interorbital constriction, 4.1 mm; breath of braincase, 8.5 mm; length of maxillary tooth rows, 6.1 mm; and mandible, 11 mm. On the basis of measurements, and coloration this specimen is tentatively assigned to *T. b. mexicana*. This is the first recorded occurrence of *T. b. mexicana* east of the Mississippi River, and is 400 mi. from the Lincoln, Nebraska, locality.

It is interesting to note that thirteen of seventeen straggler records are from late fall, which tends to show this migratory bat wanders extensively during fall migration.

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Manuscript received, November 1, 1969

SYMPOSIUM ON MAN-MADE LAKES
THEIR PROBLEMS AND ENVIRONMENTAL EFFECTS

An International Symposium on Man-Made Lakes, Their Problems and Environmental Effects will be held at Knoxville, Tennessee, U.S.A., on May 3-7, 1971. The conference should be of interest to a broad range of scientists, engineers, and project managers.

The conference is being organized by the Scientific Committee on Water Research (COWAR) on behalf of the International Council of Scientific Unions (ICSU). Numerous Unions and Committees of ICSU are cooperating, and agencies of the United Nations are providing support. Arrangements in the United States are by the National Academy of Sciences and the Tennessee Valley Authority (TVA).

The Symposium will assess recent findings, summarize knowledge, and point to needed research on man-made lakes. Principal topics will be water temperature and chemical quality; aquatic ecosystems including eutrophication, aquatic weeds, and fishery biology; siltation including amounts, control, and removal; effects upon adjoining terrestrial ecosystems; seepage; microclimate and evaporation; fishery development; resettlement and marginal agriculture; public health effects including water vectors, insects, and water quality; seismic problems; and recreation and transportation effects.

The Symposium will be organized around (1) broad, interdisciplinary case studies of the world's great man-made lakes and collections of lakes, (2) regional summaries and discussion of the several conference topics, and (3) visits to TVA projects and other facilities of interest. All sessions will be plenary. Individual papers are invited, and those which are accepted will be summarized and discussed at the Symposium and reproduced in full in the Proceedings. Abstracts are solicited before July 1, 1970.

Address all inquiries regarding attendance and participation to:

Prof. William C. Ackermann,
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Scientific Committee on Water Research
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THE SELECTED-ELECTRON-SHELL METHOD
PART I: THEORY

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ABSTRACT.—The representation of the electron density of atoms by Gaussian distribution was suggested by Ewald (1940). The analytical expression of the atomic scattering factor can then be given by a Gaussian polynomial, from which a new method, the selected- electron-shell (SES) method, is developed that allows one to analyze independently the role of the inner and outer electrons of an atom in a crystal from x-ray diffraction data. It is shown that it is also possible to study the thermal vibrations of a non-rigid atom. By comparing the electron density obtained by the SES method and the one calculated by convolution method, important details as the existence of mid-bond electrons, or polarization of the electron cloud can be investigated.

It is a well known fact that the electron density in a crystal can be studied via x-ray diffraction experiments. However, the electron density obtained by Fourier summation from experimental data is not accurate enough to allow the study of the true electron density distribution of atoms in the solid. This is due to several inaccuracies in the traditional method. Above all, the experimental method, which necessarily uses a given x-ray wavelength, introduces an important limitation resulting in what is known as the series termination effect. Moreover, in the calculations it is customary to use the atomic scattering factor of atoms considered as rigid bodies with spherical symmetry, although several authors (see, for instance, McWeeney, 1951, 1952, 1953 and 1954) have pointed out that the atomic scattering function of a bonded atom is an anisotropic function. In order to overcome the restriction imposed by considering as spherical the atoms in the crystals, it is assumed that the departure from such spherical symmetry is caused by anisotropic thermal motion of the atoms in the solid, although serious doubts have been risen (Coppens, 1968) about the legitimacy of the procedure. Furthermore, difference Fourier syntheses have shown, time and again, that residual electron density in covalently bonded atoms occurs along the bonding direction, and consequently that the electron density of real atoms in crystals is far from being spherical.

There is no easy way however to overcome the limitations and inaccuracies of the traditional path. It is therefore necessary to seek a new solution of the problem. The present authors have shown in a previous paper (Amorós and Canut-Amorós, 1968) that it is possible to sepa-

rate the contributions to x-ray diffraction of the inner and outer electrons of atoms in molecular crystals. A simple description of the basic ideas has also been introduced in a recent book (J. L. and Marisa Amorós, 1968). The basic idea is to use Gaussian polynomials as the analytical representation of the atomic scattering function. The method is based on the separate treatment of such contributions by associating them with the traditionally accepted shell structure of the atoms, and the method can be called, appropriately, the selected-electron-shell (SES) method. In what follows, we shall describe the basic theory of the SES method. In order to implement the method, some computational aids have been developed in our Laboratory. A brief description of the programs and some results obtained by using such computational aids are included in the second part of this paper.

The selected-electron-shell approach

The method assumes that the electron density of an atom can be given analytically by Gaussian polynomials. The representation of the electron density function of an atom by a Gaussian distribution was first introduced by Ewald (1940) in his Gaussian atom model. The use of Gaussian functions is very convenient, because the Fourier transform of a Gaussian function of width g is also a Gaussian function of width $1/\pi g$. Therefore the atomic scattering function of a Gaussian atom is also given by a Gaussian function. It was shown later (Vand, Eiland and Pepinsky, 1957; Hosemann and Bagchi, 1962) that a better fit of the atomic scattering factor was obtained by using a Gaussian polynomial instead of a single Gaussian function. Along these lines, Moore (1963), Cromer and Waber (1964) and Kurki-Suonio, Meisalo, Merisalo and Peltola (1966) have given different sets of Gaussian polynomials that describe the scattering factor of different atoms. However, the use of Gaussian polynomials has physical meaning only when each Gaussian term of the polynomial is associated to the electron distribution of each main electron shell of the atom. In this case, the atomic-scattering amplitude can be expressed (Amoros and Canut-Amoros, 1968) by

$$\underset{\sim}{f}(\underset{\sim}{r}^*) = \sum_{s=1}^{S} \underset{\sim}{G}_s \exp(-\pi^2 \underset{\sim}{g}_s^2 \underset{\sim}{r}^{*2}), \quad (1)$$

where G_s is the number of electrons in the s shell, g_s is the half width of the Gaussian function of the same shell, and r^* is the magnitude of the reciprocal vector. The summation extends to the S shells of the atom. Expression (1) is very convenient because it allows one to determine the Gaussian coefficients G_s and g_s from a semilogarithmic plot of the observed or theoretical scattering amplitude of the atom versus $|r^*|^2$.

Expression (1) corresponds to the scattering amplitude of an atom at rest. In real crystals, however, atoms are subject to thermal vibrations. For simplicity, let us assume that the atom vibrates isotropically in an harmonic potential field. The smearing function is given by a Gaussian probability p(r) that is temperature dependent. Then the atomic scattering amplitude is modi-

fied by a temperature factor. The Fourier transform of p(r) is

$$D_T(\underline{r}^*) = \exp(-\pi^2\, 2\underline{u}_T^{-2}\, \underline{r}^{*2}), \quad (2)$$

where u_T is the mean square amplitude of vibration of the atom. $D_T(r^*)$ is also a Gaussian function. The effective atomic-scattering amplitude at the temperature T is then corrected by the temperature factor, i.e.,

$$\underline{f}_T(\underline{r}^*) = \underline{f}(\underline{r}^*) \cdot \underline{D}_T(\underline{r}^*), \quad (3)$$

if the atom vibrates as a rigid body. The obvious consequence, long ago recognized in x-ray diffraction analysis, is that the effective atomic-scattering amplitude of the vibrating atom is temperature dependent. Equation (3) can be written explicitly in terms of the Gaussian components of the atomic scattering amplitude, i.e.,

$$\underline{f}_T(\underline{r}^*) = \sum_{\underline{s}}^{\underline{S}} \underline{G}_s \exp(-\pi^2\, \underline{g}_{sT}^{\,2}\, \underline{r}^{*2}), \quad (4)$$

where the new Gaussian parameter g_{sT} is now given by

$$\underline{g}_{sT} = (\underline{g}_s^{\,2} + 2\underline{u}_T^{-2})^{1/2}. \quad (5)$$

From (5) it follows that the only consequence on introducing an harmonic vibration on (1) is to vary the width of the Gaussian function. We have assumed the rigid-atom approximation to deduce (3). However, once the Gaussian components are explicitly introduced in the expression of the atomic-scattering amplitude (4), this restriction is no longer necessary, and the rigid atomic shell approximation can now be introduced, in which each atomic shell can vibrate with a different amplitude u_{sT}. Under this assumption (5) becomes

$$\underline{g}'_{sT} = (\underline{g}_s^{\,2} + 2\underline{u}_{sT}^{-2})^{1/2}, \quad (6)$$

and (4) accordingly can be rewritten as

$$\underline{f}_T(\underline{r}^*) = \sum_{\underline{s}}^{\underline{S}} \underline{G}_s \exp(-\pi^2\, \underline{g}'^{\,2}_{sT}\, \underline{r}^*)^2. \quad (7)$$

The analytical approximation of the atomic scattering factor is therefore very convenient since it allows one to determine the temperature factor of the different shells independently. In the conventional method used in x-ray crystallography, only rigid atoms are assumed. Several hints exist, however, that this is not the case, and this method may prove useful in obtaining conclusive evidence on this matter.

In crystal-structure determination the temperature factor is usually expressed as

$$\underline{D}_T([\sin\theta]/\lambda) = \exp(-\underline{B}_T[\sin^2\theta]/\lambda^2), \quad (8)$$

where B_T is related to the mean square vibrational amplitude by

$$\underline{B}_T = 8\pi^2\, \underline{u}_T^{-2}, \quad (9)$$

for isotropic rigid body motion. The B_T factor can be introduced in the Gaussian width, which then takes the form

$$\underline{g}_{sT} = \left(\underline{g}_s^{\,2} + \frac{\underline{B}_T}{4\pi^2}\right)^{1/2}, \quad (10)$$

where g_s is the form coefficient of the Gaussian describing the s electron shell at rest.

If we express the atomic-scattering

amplitude as a function of $(\sin\Theta)/\lambda$ instead of r*, the following expression is obtained:

$$f_T([\sin\theta]/\lambda) = \sum_s G_s \exp(-4\pi^2 g_s^2[\sin^2\theta]/\lambda^2) \exp(-B_T[\sin^2\theta]/\lambda^2), \quad (11)$$

or else

$$f_T([\sin\theta]/\lambda) = \sum_s G_s \exp(-B''_{sT}[\sin^2\theta]/\lambda^2), \quad (12)$$

with the same temperature factor B_T for each s shell

$$B''_{sT} = 4\pi^2 g_s^2 + B_T, \quad (13)$$

i.e., in the rigid body atom approach.

In the rigid atomic shell approach, one can introduce temperature factors B_{sT} associated to each shell s, and define

$$B'_{sT} = 4\pi^2 g_s^2 + B_{sT}, \quad (14)$$

where

$$B_{sT} = 8\pi^2 \bar{u}_{sT}^2. \quad (15)$$

B'_{sT} can be deduced from x-ray diffraction experiments, in terms of

$$f_T([\sin\theta]/\lambda) = \sum_s G_s \exp(-B'_{sT}[\sin^2\theta]/\lambda^2). \quad (16)$$

Let us remember that the coefficients B'_{sT} contain both the form and temperature factor of the Gaussian describing the rigid electron shell s.

X-ray crystal-structure analysis is done by means of finding the best fit between observed and calculated structure factors. The conventional structure-factor equation is well known. In the isotropic case, we have

$$F(r^*_h) = \sum_j \sum_s G_{js} \exp(-B''_{js}[\sin^2\theta]/\lambda^2) \exp(-2\pi i\, r_j \cdot r^*_h), \quad (17)$$

when the Gaussian components of the atomic scattering amplitude are explicitly introduced. The new summation extends to the S electron shells of the atom j, and B''_{js} has the meaning defined by (13).

If we deal with a structure that has been well-refined by the conventional method, it is reasonable to assume that the coordinates r_j of the atoms are well determined. We may then accept those coordinates as known constants. But even in the case where conventional thermal analysis is assumed to be satisfactory, i.e., that we know the exponents B_{jT} for the different atoms in the structure, we are forced to determine the new B'_{js} as they now contain the as they now contain the temperature and the Gaussian parameters of a rigid shell. These values can be obtained through a least squares refinement, by using the B''_{js} as starting values. The new parameters B'_{js} contain information about the average electron density of the given shell of the atom at the temperature at which the observations have been made.

We know (Slater, 1965) that in molecular structures a bond depends on the overlapping of charge in the outer shells of the two bonded atoms. This overlapping is expected to be at a maximum when the maximum charge densities of the outer shells of the two atoms coincide. The anisotropy in the electron density of the atoms of a molecule depends, then, on the contribution of the outer electrons alone and this anisotropy will be modified to some extent by thermal motion. The distribution of the inner electrons however is expected to be spherically symmetric. Then any anisotropy observed in the distribution of the inner electrons must come from the distortion produced by the anisotropy of the thermal motion alone. This gives a good way to determine with high accuracy the thermal motion of the atomic nuclei and the inner electrons tightly bonded to them. In molecular crystals with C, N, O and H, the region outside a limiting sphere of r^* about 0.9 $Å^{-1}$ contains the contribution of the inner electrons alone. In this case, it is possible to deduce for the shell K the best values of B'_{jk} using only experimental data obtained from high diffraction angles. The structure factor for reflections in this region is then given by

$$\underset{\sim}{F}(\underset{\sim}{r}^*_{\underline{h}}) = \underline{F}_K(\underset{\sim}{r}^*_{\underline{h}}) = \sum_{\underline{j}}^{\underline{J}} \underline{G}_{jK} \exp(-\underline{B}'_{jK}[\sin^2\theta]/\lambda^2) \exp(-2\pi i\, \underset{\sim}{r}_j \cdot \underset{\sim}{r}^*_{\underline{h}}), \quad (|\underset{\sim}{r}^*_{\underline{h}}| \geq \underline{R}_{L\ \mathrm{lim}}), \tag{18}$$

where $R_{L\ lim}$ corresponds to the region where the outer electrons no longer contribute.

Up to now, we have considered isotropic thermal motion, however atoms in real crystals are in general subjected to anisotropic thermal vibrations. The simplest case of this kind of thermal motion is represented by a second rank symmetric tensor **U**. In this case the temperature factor B is transformed into another tensor **B** related to **U** by

$$\underset{\sim}{B} = \frac{\underset{\sim}{U}}{8\pi^2}. \tag{19}$$

We can then write

$$\underline{D}(\underline{r}^*) = \exp[-(\Sigma\Sigma \underline{B}_{ij}\, \underline{m}_i \underline{m}_j)(\sin^2\theta)/\lambda^2]. \tag{20}$$

In this expression, **m** is a unit vector in reciprocal space and $\Sigma\Sigma B_{ij}\, m_i m_j$ can be considered as the value of **B** in the direction of **m**. For the sake of computation, the temperature factor D in (20) is usually expressed in terms of dimensionless quantities β_{ij} as follows:

$$\underline{D} = \exp[-(\beta_{11}\underline{h}^2 + \beta_{22}\underline{k}^2 + \beta_{33}\underline{\ell}^2 + 2\beta_{12}\underline{hk} + 2\beta_{13}\underline{h\ell} + 2\beta_{23}\underline{k\ell})]. \tag{21}$$

The following known relations exist between β_{ij} and B_{ij}:

$$\underset{\sim}{B}_{11} = \frac{4\beta_{11}}{\underset{\sim}{a}^{*2}} \qquad \underset{\sim}{B}_{22} = \frac{4\beta_{22}}{\underset{\sim}{b}^{*2}}$$

$$\underset{\sim}{B}_{33} = \frac{4\beta_{33}}{\underset{\sim}{c}^{*2}} \qquad \underset{\sim}{B}_{12} = \frac{4\beta_{12}}{\underset{\sim}{a}^{*}\underset{\sim}{b}^{*}}$$

$$\underset{\sim}{B}_{13} = \frac{4\beta_{13}}{\underset{\sim}{a}^{*}\underset{\sim}{c}^{*}} \qquad \underset{\sim}{B}_{23} = \frac{4\beta_{23}}{\underset{\sim}{b}^{*}\underset{\sim}{c}^{*}} \qquad (22)$$

Assuming anisotropic thermal vibrations, B'_{jk}, in (18) must be substituted for B'_{jk} the tensor that includes both the spherically symmetric form factor and the anisotropic temperature factor of the K shell.

Once the best values of the Gaussian parameters of the shell describing the inner electrons have been determined by least squares refinement using high order diffraction data, it is just a matter of routine to calculate the contribution F_k of these electrons to every observed x-ray diffraction data. The observed amplitudes F_{obs} contain the contribution of all the electrons in the crystal. We can calculate a Fourier series of the form

$$\rho_{outer}(\underset{\sim}{r}) = \Sigma_{\underset{\sim}{h}} \left(\underset{\sim}{F}_{obs} - \underset{\sim}{F}_{K}\right) \exp(2\pi i\, \underset{\sim}{r} \cdot \underset{\sim}{r}^{*}_{h}),$$

$$(|\underset{\sim}{r}^{*}_{h}| < \underset{\sim}{R}_{L\ lim}), \qquad (23)$$

that has important properties. First, it is free from series termination effects, because the coefficients in (23) are zero outside $R_{L\ lim}$. Second, it contains the information of the most important electrons, the outer electrons, in the bonding system of a molecule. It contains also the contribution of the hydrogen atoms if they are present in the structure. The $(F_{obs} - F_k)$ Fourier summation is fundamental in the analysis of the electron distribution in a molecule and it is the basic equation in the SES method.

Calculation of the electron density by convolution method

The purpose of the method outlined in this paper is not only to get the best fitting atomic scattering amplitude of the atoms in a given crystal structure, and to obtain a display of the experimental density function of the outer electrons, but also to compare this electron density distribution with the calculated one in terms of the different Gaussian atoms, considered as a whole or as individual contributions of the shells. Consequently the last step of the SES method is the theoretical calculation of the electron density of a crystal. We shall deal now with this problem.

The electron density of an atom is the inverse Fourier transform of its atomic scattering amplitude. It follows from what has been said at the beginning of our discussion that the electron density in the Gaussian approximation is given by the Gaussian polynomial

$$\rho(\underset{\sim}{r}) = \sum_{s=1}^{S} \frac{G_s}{(\pi g_s^2)^{3/2}} \exp\left(-\frac{1}{g_s^2}\underset{\sim}{r}^2\right), \quad (24)$$

that is readily obtained from (1). In a similar way, by applying a Fourier transformation to (7), one obtains,

$$\rho_T(\underset{\sim}{r}) = \sum_{s=1}^{S} \frac{G_s}{(\pi g'^2_{sT})^{3/2}} \exp\left(-\frac{1}{g'^2_{sT}}\underset{\sim}{r}^2\right) . \quad (25)$$

From least squares refinement, the B'_{sT} values are obtained rather than g'_{sT}. However those can be readily obtained because

$$g'_{sT} = \frac{\sqrt{B'_{sT}}}{2\pi} = 0.1591\sqrt{B'_{sT}} . \quad (26)$$

The new equation (25) gives the averaged electron-density of the Gaussian atom spread by the thermal motion.

The electron density inside a unit cell of the crystal can be calculated by convolving the Gaussian functions (25) describing the different atoms with the atomic peak functions $z_j(\mathbf{r})$ that define the coordinates of the atoms in the unit cell,

$$\rho_{cell}(\underset{\sim}{r}) = \sum_{j=1}^{J}\sum_{s}^{S} \rho_{jsT}(\underset{\sim}{r}) * z_j(\underset{\sim}{r}) . \quad (27)$$

The electron density calculated from (27) represents the assumption of a spherically symmetric Gaussian distribution of the electrons in the different shells of the atom. To introduce a non-spherical symmetry, the coefficient g'_{sT} must be substituted for a second rank tensor.

The electron density maps obtained by convolution are very convenient for the analysis of the experimental SES maps. Differences between the two maps will appear if the observed electron density is not only due to the overlap of the outer electrons, but also to the presence of mid-bond extra electrons or the existence of polarization of the electron cloud. These are basic questions of interest to chemists and physicists alike, and the SES method may prove fruitful in such cases. The SES method is basically an experimental method and, as in any experimental approach, the results obtained depend largely upon the accuracy of the experimental data and of the corrections applied to them. The observed $F_o(hkl)$ values should be corrected for Compton and thermal diffuse scattering, and extinction must be taken care of. Preliminary research on organic compounds (Amorós and Canut-Amorós, 1968a, b), inorganic covalent crystals (Amorós, Canut-Amorós, and Montoto, 1968) and ionic compounds (Savanonda, 1968) has shown the validity of the theory and the plausibility of the method.

Acknowledgments

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THE SELECTED-ELECTRON-SHELL METHOD
PART II: IMPLEMENTATION

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ABSTRACT.—The basic steps in applying the selected-electron-shell method to the analysis of the electron density of a crystal are given. In order to implement the method, several computing programs have been developed: LNPLT — Semi-logarithmic plot of x-ray scattering or structure factors; RVPUN — HKL structure factor data cards with reciprocal vector; GSFPLT — Gaussian scattering factor plot; TFCNV — Temperature factor conversion; CONVU — Electron density functions by convolution; DIFTAP — Difference tape; PFPLT — Peak function plot; and ADDATA — Data tape. Three of them, LNPLT, GSFPLT and CONVU, are especially interesting because they provide graphical plots needed for the application of the SES method. Examples of their use in actual cases are given.

The selected-electron-shell method, the theory of which has been given in Part I of this paper, could not have been developed at all as a practical tool without the proper development of a set of computing programs that would implement it. The purpose of the present paper is to give the general philosophy of the computing aids developed in connection with the SES method and to illustrate the application of the programs with examples. A detailed description of the programs, their write-ups and listings is given in a recent report (Marisa Canut-Amoros, Casper and Walters, 1968) and therefore they will not be given here.

BASIC STEPS OF THE SES METHOD

The SES method requires the following operational steps:

(1) It is necessary to express the atomic scattering amplitude in terms of a Gaussian function for each atomic shell. This requires the determination of the number of electrons G_s in the shell and the form factor of the Gaussian given by the exponent g_s (See Equation [1] in Part I).

(2) The different shells contribute only up to certain regions in Fourier space. The limit is set by the exponent g_s of the corresponding Gaussian. In order to independently analyze such a contribution, the observed structure factors must be sorted according to their reciprocal vector. This is a must for the refining of the Gaussian function describing the inner electrons.

(3) Once step (2) has been accomplished, the observed x-ray diffraction amplitudes can be used for the least squares refinement of the shell Gaussians. Before conducting the refinement, however, it is necessary to transform the temperature factors as obtained from conventional crystal structure determination into suitable expressions for Gaussian analysis (Equation [13] of Part I).

(4) Once the best Gaussian parameters have been determined, it is desirable to calculate the contributions and their sums of the different electronic shells of an atom. Therefore, the atomic scattering amplitude, the atomic electron density distribution, and its radial distribution as given by the analytical method need to be plotted and compared with the standard values.

(5) The structure factors of the different crystal planes (hkl) can now be calculated using the analytical expression for the atomic scattering amplitudes. Contributions by the individual shells to the structure factors can also be calculated.

(6) Once step (5) is done, the SES electron density map of the outer electrons can be calculated using Equation [23] of Part I.

(7) In order to compare the observed and theoretical SES electron density, we must calculate the theoretical electron density by convolution method using polynomial expressions for the atomic Gaussian density functions (Equation [27] of Part I).

(8) Difference maps between observed and theoretical SES electron density are in order to check the validity of the assumptions used in the derivation of the analytical expressions and to find the corrections that are further needed, such as the existence of electron density in the mid-bond.

The least squares refinement of the Gaussian parameters can be done using in an unorthodox way the excellent crystallographic program ORLSF of Busing, Martin and Levy (1964). The program allows the refinement of the coordinates and thermal parameters of the atoms in a crystal structure using experimental data obtained either from x-ray or neutron diffraction methods. We use the neutron diffraction version of the program by treating the number of electrons of the shell as a neutron scattering factor. The values B'_{jsT} (Equation [14], Part I) can now be determined by least squares method directly with the program.

In order to calculate the SES electron density maps, two sets of F(hkl) values must be obtained with the ORLSF program. The first set consists of the $\pm A_o$ and $\pm B_o$ parts of the observed structure amplitudes after the final cycle of least squares refinement. The second set consists of the $\pm A_k$ and $\pm B_k$ parts of the calculated structure amplitudes corresponding to the inner electrons alone. Such information is stored in two scratch tapes. A small *ad hoc* program DIFTAP allows one to obtain a new tape storing the differences $A_o - A_k$ and $B_o - B_k$ to be used as coefficients in the SES-Fourier series (Equation [23] of Part I). The outer-electrons density maps are then calculated by using the Fourier program of Zalkin (1962), modified (FORPLN) as to generating a tape that is used as input in our contour plot program (CNTPLT) especially written for us by Notestine.

Besides those programs currently available, several supporting programs have been developed to implement other steps required by the SES method. Those programs are: LNPLT — Semilogarithmic plot of x-ray scattering or structure factors; RVPUN — HKL structure factor

data cards with reciprocal vector; GSFPLT — Gaussian scattering factor plot; TFCNV — Temperature factor conversion; CONVU — Electron density functions by convolution; DIFTAP — Difference tape; PFPLT — Peak function plot; and ADDATA — Data tape. In what follows, the LNPLT, GSFPLT, and CONVU programs will be briefly described and basic examples of their use will be given.

LNPLT—Semilogarithmic Plot of X-ray Scattering (or Structure) Factors

The starting point of the SES method is to determine the Gaussian components of the x-ray atomic scattering factor. A convenient method is through a graph in which the logarithm of the atomic scattering factor is plotted versus $|r^*|^2$, the reciprocal vector. The purpose of the LNPLT program is to provide such a plot. The program uses as logarithmic axis the Y axis of the plotter, and $|r^*|^2$ is plotted along the X axis of the plotter. Due to the geometry of the CalComp model used, the maximum height desired in the logarithmic scale is set up by the program to a length of 25 cm. The axis representing $|r^*|^2$ (in $Å^{-2}$) can be plotted at any desired scale (a convenient size is $1Å^{-2} = 5$ cm.). In order to help in visualizing the different regions of diffraction space, dotted lines are plotted defining the limiting diffraction conditions for the x-ray characteristic radiations of Cu and Mo.

Once the logarithmic plot of the given atomic scattering factor (the values can be obtained from standard tables) has been performed by LNPLT, the Gaussian constants G_s and g_s appearing in

$$f(r^*) = \sum_{s=1}^{S} G_s \exp(-\pi^2 g_s^2 r^{*2}), \quad (1)$$

are easily obtained with the help of this plot. A straight line passing through a set of successive points indicates that such set of values can be analytically described by a Gaussian. The intercept of this line at the zero ordinate gives G_s, the number of electrons in the s shell; g_s is derived from the slope of the line in the following way. If $|r^{*1}|^2$ is the value along the X axis corresponding to $G_s/2$, from (1), one can obtain

$$\ln G_s/2 = \ln G_s - \pi^2 g_s^2 r^{*2}, \quad (2)$$

from which

$$g_s^2 = 0.0702 \frac{1}{r^{*2}} . \quad (3)$$

By using (3) the value of g_s^2 can be can be directly obtained just by reading in the semilogarithmic plot the value of r^{*2} for which the function has the value of $G_s/2$.

The Gaussian components of the scattering factor can be determined from the plot by an iterative analysis. First one must start with the Gaussian function of lower electronic content. The differences between this function and the total atomic scattering factor allow one to determine other Gaussian components by treating the residuals in a way similar to the first case. An actual example can be seen in Figure 1 that gives the Gaussian functions describing the x-ray scattering factor

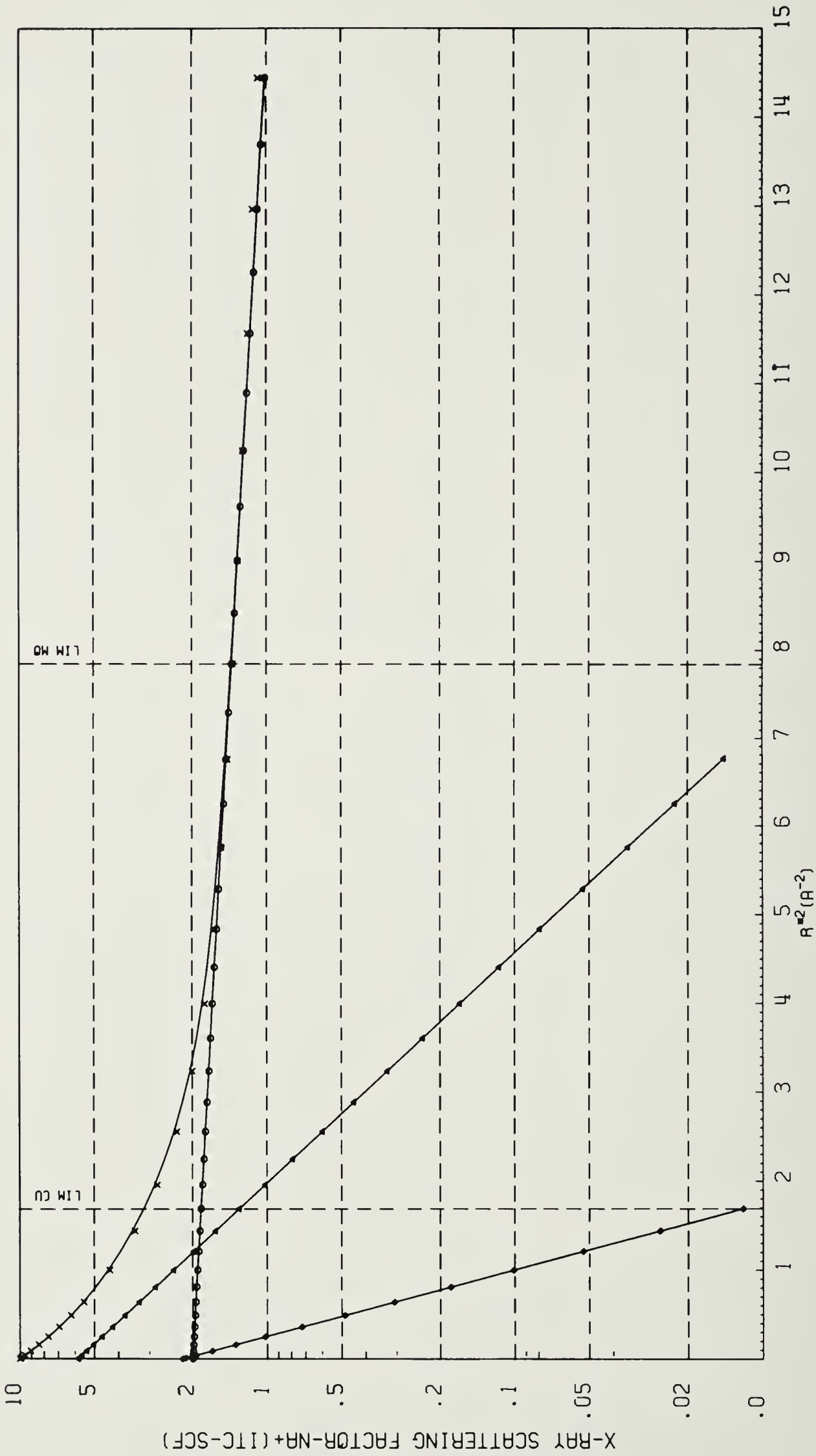

FIGURE 1. Example of plot involving LNPLT. Semilogarithmic plot of the atomic scattering factor of Na^+ and its Gaussian components.

of ionic Na. The original values given in the International Tables for X-ray Crystallography (1956) are given in the graph by crosses. The first Gaussian determined is the one with two electrons. From the differences between the original values and the corresponding ones of this first Gaussian, a second Gaussian with six electrons can be determined. Finally, the difference between the sum of these two Gaussians and the original values allows us to determine a third Gaussian with two electrons. The Gaussian parameters so determined can be introduced in the Gaussian polynomial (1), and the following expression is obtained for the scattering factor of ionic sodium:

$$\begin{aligned} \underset{\sim}{f}_{Na^+}\ (\underset{\sim}{r}^*) = {} & 2\ \exp(-\pi^2 g_K^2\ \underset{\sim}{r}^{*2}) \\ & + 6\ \exp(-\pi^2 g_{L_1}^2\ \underset{\sim}{r}^{*2}) \\ & + 2\ \exp(-\pi^2 g_{L_2}^2\ \underset{\sim}{r}^{*2}), \end{aligned} \tag{4}$$

where the first summand corresponds to the K shell, the second to the L_1 shell and the third to the L_2 shell of sodium.

Once G_1, g_1, G_2, g_2, . . . have been determined with the help of the LNPLT plot, the program GSFPLT allows one to compute (1) at given increments Δr^* up to a maximum value $|r^*_{max}|$. The calculated scattering factor is given in Figure 1 by the continuous line that overlaps with the original values, showing how closely the sum of the individual Gaussian fits.

In the graph, the limits of λ for Cu and Mo characteristic radiations are also given. If we are interested in working with data obtained with Cu radiation, a blow-up of the graph in this region is desired, as seen in Figure 2.

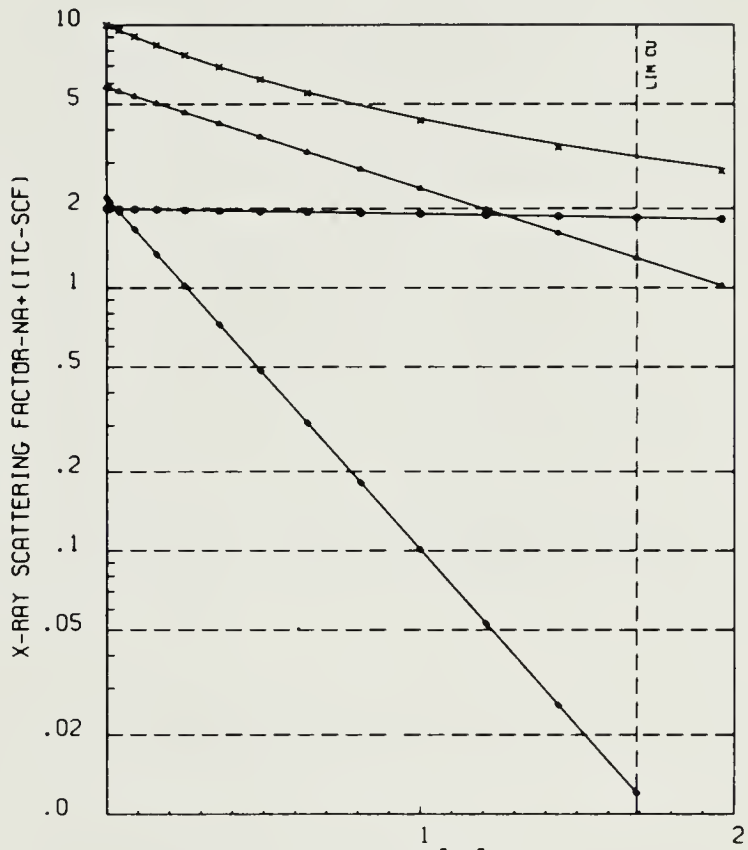

FIGURE 2. Example of plot involving LNPLT. Blow-up of Figure 1 covering the region for Cu X-ray radiation.

When dealing with simple structures, it is convenient to plot the observed amplitudes in terms of $|r^*|^2$. Such plotting in the case of NaCl, for instance, represents the experimental amplitudes corresponding to the sum or the difference of the atomic scattering factors of Na^- and Cl^-. From a plot such as Figure 3, the actual experimental curves of both atomic scattering factors can be determined. In order to plot this set of data associated to every hkl, the value of $|r^*(hkl)|$ is needed. If this value is not given in the literature along with $F_o(hkl)$, the RVPUN program needs to be previously used to compute $|r^*(hkl)|$ for every $F_o(hkl)$.

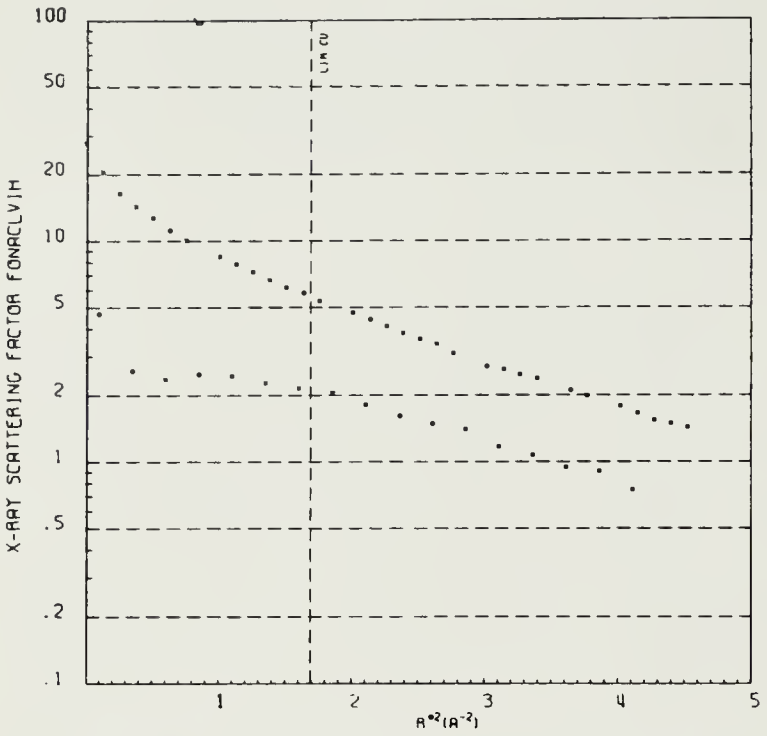

FIGURE 3. Example of plot involving LNPLT. Semilogarithmic plot of the observed structure factors of NaCl.

GSFPLT—GAUSSIAN ATOMIC FUNTIONS PLOT

Once the Gaussian parameters of the Gaussian polynomial have been deduced from the LNPLT plot or from least squares refinement, it is convenient to obtain the atomic scattering factor curve in a suitable manner for its use and, in order to analyze the role of the different shell components, to calculate as well the atomic electron density and its radial distribution. For this purpose, the GSFPLT program was developed.

The basic equations used by the program are the following. The Gaussian polynomial that describes the atomic scattering function is given by (1). The atomic electron density as the Fourier transform of the atomic scattering function is expressed by

$$\rho(\underline{r}) = \sum_{\underline{s}=1}^{\underline{S}} \frac{\underline{G}_{\underline{s}}}{\sqrt{(\pi \underline{g}_{\underline{s}})^{3/2}}} \exp\left(-\frac{1}{\underline{g}_{\underline{s}}^{2}} \underline{r}^{2}\right), \quad (5)$$

where G_s and g_s are the same as in (1).

The radial distribution of the electron density is given by

$$U(\underline{r}) = \sum_{\underline{s}=1}^{\underline{S}} 4\pi \underline{r}^{2} \rho_{\underline{s}}(\underline{r}). \quad (6)$$

GSFPLT computes $f(r^*)$ from Equation (1) at desired equal increments of Δr^* up to a given r^*_{max} (in $Å^{-1}$). It also computes $\rho(r)$ and $U(r)$ according to equations (5) and (6), respectively, at desired equal increments of Δr up to a given r_{max} (in Å). Punch cards can be obtained for $f(r^*)$ and its Gaussian components. If the increment is chosen $\Delta r^* = 0.1Å^{-1}$ and $r^*_{max} = 5.0\ Å^{-1}$, these cards can be used in LNPLT to check the Gaussian approximation used with the starting values and also to obtain the final LNPLT map (Figures 1a and 1b).

This check can be also done in a direct way by the present program by plotting in the same graph the original data $f(r^*)$ and $\Sigma_s f_s(r^*)$ as well as the individual components $f_s(r^*)$. An example of this kind of graph is given in Figure 4 that corresponds to the scattering factor of Na^- versus r^*. A plot of this kind would clearly indicate that the effect

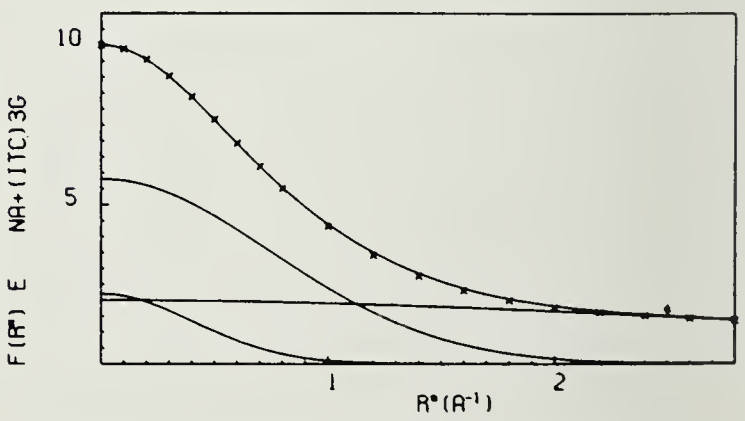

FIGURE 4. Example of plot involving GSFPLT. Scattering factor of Na^+ and its Gaussian components.

of the inner electrons of the atom (K shell) extends over all the diffraction space. But on the contrary, the effect of the outermost electrons (L_2 shell) extends only up to about 1 $Å^{-1}$ and therefore only the information near the origin of diffraction space must be used if we are interested in analyzing their distribution.

A series of graphs of this kind may be very useful if we are interested in studying the effect of thermal vibrations on the atomic functions. Thermal vibrations have a very decisive influence in the Gaussians describing the core electrons of an atom, but they have very little effect on the outermost electrons. This fact can be easily visualized from the plots of the electron density of the atom and its radial distribution, that can be obtained with the GSFPLT program (Figures 5 and 6.). Especially interesting are Figures 6a and 6b, which substantiate the assumption used in theoretical chemistry, that the overlap integral of the outer electrons is temperature independent. In fact, the radial distribution of the

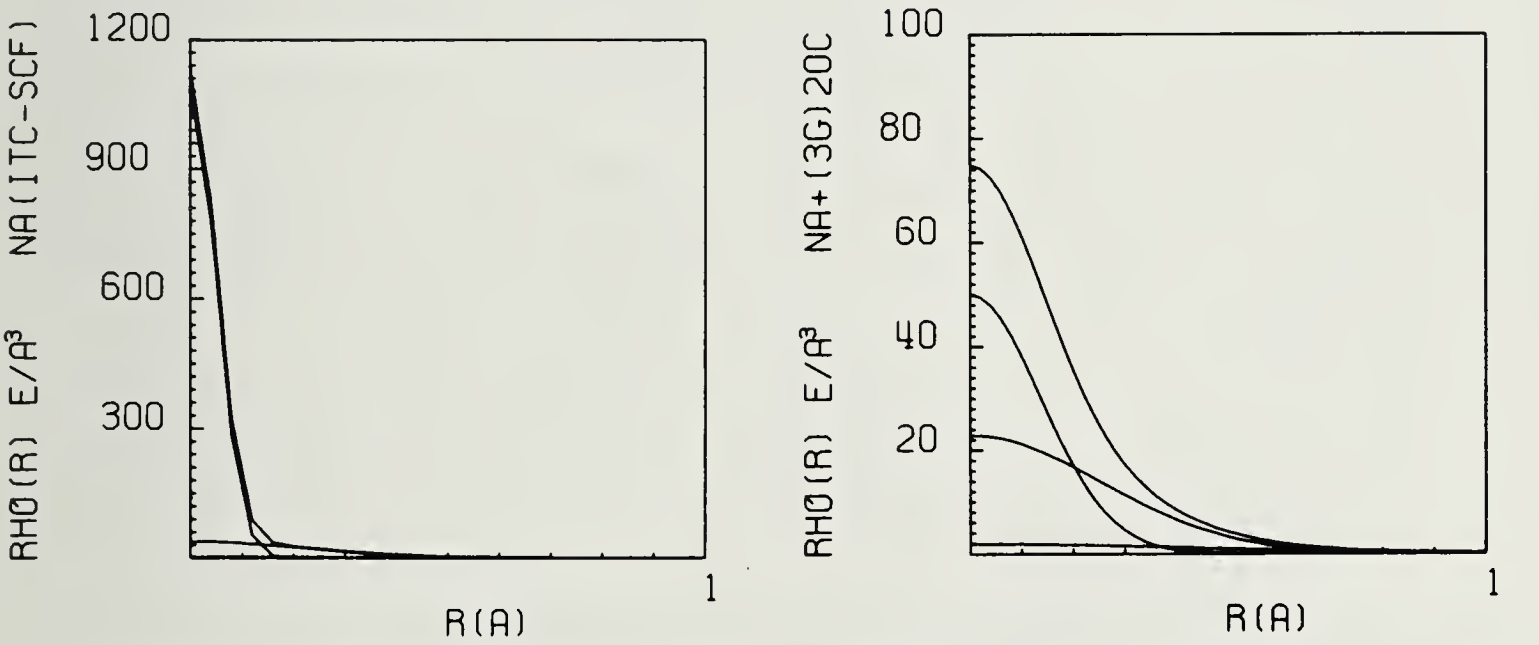

FIGURE 5. Examples of plots involving GSFPLT. (*a*) Electron density of Na^+ at rest, and (*b*) at 20°C.

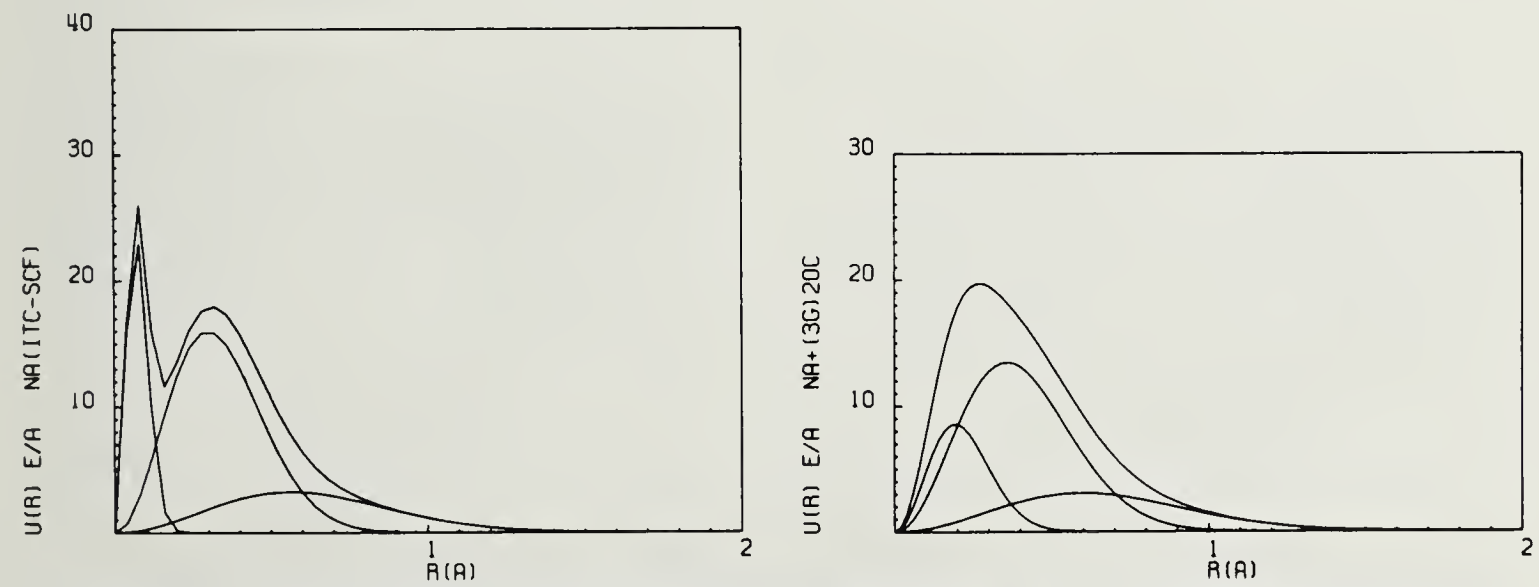

FIGURE 6. Examples of plots involving GSFPLT. (*a*) Radial distribution of the electron density of Na^+ at rest, and (*b*) at 20°C.

outer shell is almost temperature independent. In this kind of study, it is convenient to have in a combined plot the radial distribution of two atoms at their distance in the crystal. This is also allowed by the program, which generates a plot of $U_1(r)$ and $U_2(r)$, the latter plotted backwards from the experimentally determined interatomic distance. Figure 7 gives such a plot for NaCl from values determined by Savanonda (1969).

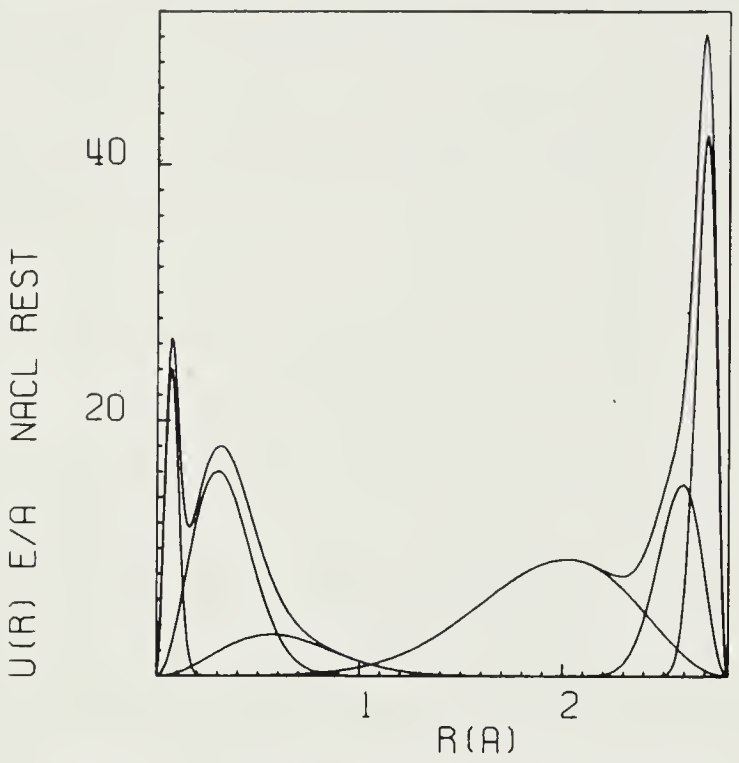

FIGURE 7. Example of plots involving GSFPLT. Radial distribution of NaCl at rest along [100].

CONVU — Electron Density by Convolution

The final goal of the SES method is to obtain a true picture of the actual distribution of the outer electrons in a crystal. We call such pictures SES maps. One example is given in Figure 8a that represents a section of the density distribution of the outer electrons in hexamine. The following question arises: Is the observed distribution due to a mere overlap of the electron density of neighboring atoms? To answer this question, it is necessary to have a way to calculate the electron density expected from the Gaussian functions determined by least squares method. Such a calculation and subsequent plotting of the electron density is provided by the CONVU program.

Once the electron density of an atom is correctly represented by a Gaussian polynomial, the total electron density of the crystal can be calculated by convolving the different Gaussian functions with the peak functions defining the atomic coordinates of the atoms in the unit cell. We can express the electron density at a point given by $\mathbf{r}$ of a sampling lattice inside the unit cell of the crystal in the following way:

$$\rho(\mathbf{r}) = \sum_{j=1}^{J} \sum_{s=1}^{S} \frac{G_{js}}{(\pi g_{js})^3} \exp\left[-\frac{1}{g_{js}^2}(\mathbf{r} - \mathbf{r}_j)^2\right], \quad (7)$$

where G_{js} is the number of electrons in the s shell of the atom j in the position $\mathbf{r}_j$ and g_{js} is the exponent of the Gaussian function of the s shell of the atom in question. The sum is extended to the J atoms of the unit cell and to the S shells of the atom.

The computation of the electron density by (7) has the advantage of allowing one to include only the desired atoms and electron shells by adequate limitation of the summations.

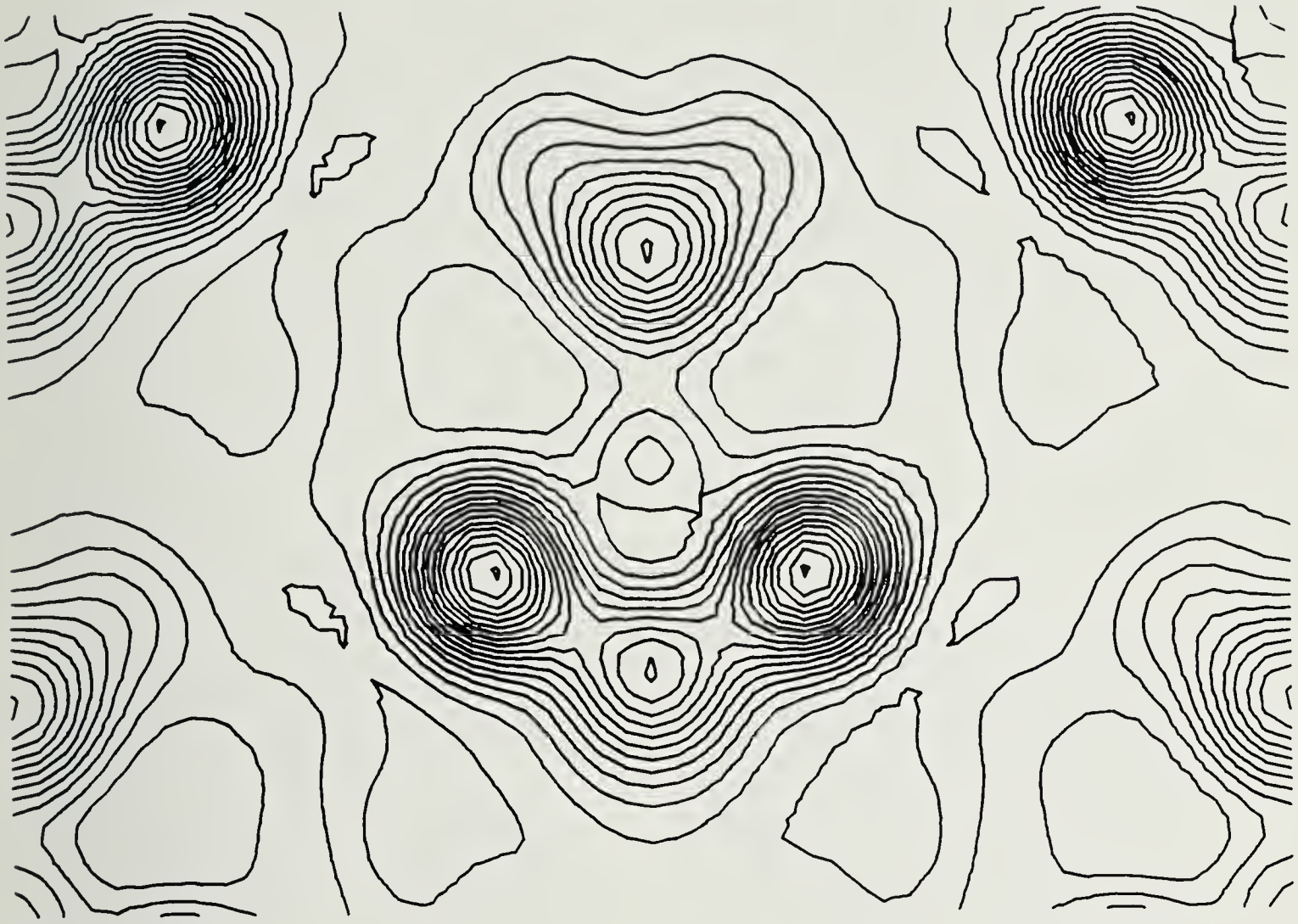

FIGURE 8. Example of plots involving CONVU. (*a*) Section [100] of the observed SES electron density of hexamine at 34°K. (*b*) Equivalent section calculated by convolution introducing hydrogen atoms. (*c*) The same without hydrogen atoms.

An interesting example of the use of the program is given in the analysis of the electron density of hexamine (Amoros and Canut-Amoros, 1969). Using this program, Figures 8b and 8c have been obtained and they correspond to the section through two carbons and two nitrogens of the molecule of hexamine. In one of the sections (Figure 8b) the hydrogen atoms attached to the carbon atom have been introduced in the calculation; the other one (Figure 8c) is without such atoms. The SES map of hexamine (Figure 8a) is completely explained by Figure 8b showing that the observed outer electron density in hexamine corresponds to the overlap of the outermost electrons only and evidencing the hydrogen atoms. No mid-bond electron density is necessary to explain the observed SES map.

A different situation is found in diamond (Montoto 1968). The SES map section through the carbon atoms is given in Figure 9a and the convolution map in Figure 9b. The observed

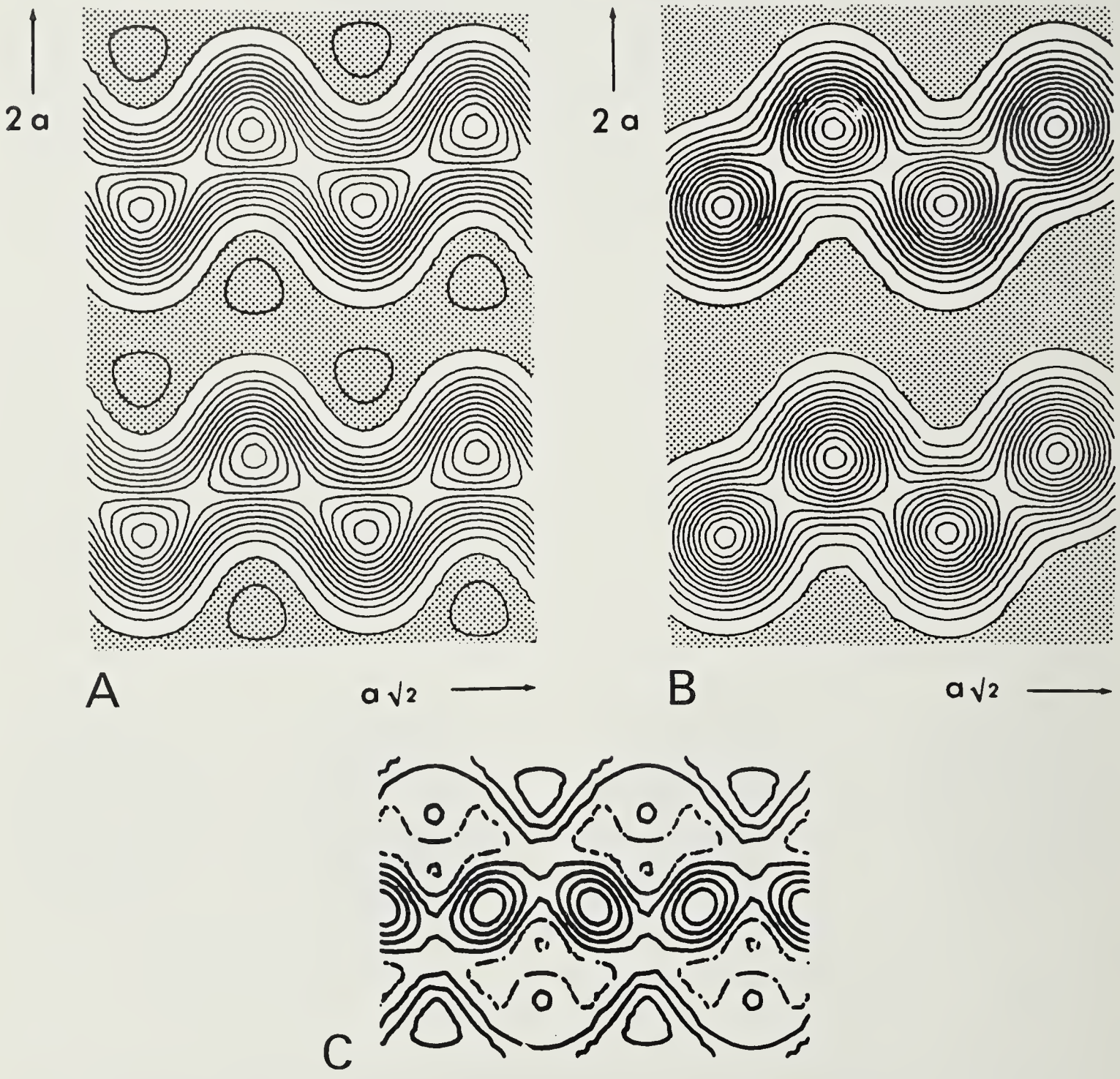

FIGURE 9. Example of plots involving CONVU. (*a*) Experimental SES electron density of diamond passing through four carbon atoms. (*b*) Equivalent section calculated by convolution. (*c*) Difference between (a) and (b).

SES map shows higher electron density in the mid-bond than that expected from convolution method. A difference between both maps can also be obtained using the DIFTAP program. The resulting Figure 9c clearly shows that a substantial electron density is present in the central part of the bond between bonded carbons, as expected from theory.

Final Remarks

The programs developed to implement the selected-electron-shell method facilitate considerably the practical use of the method developed in Part I. Besides the basic operations performed by LNPLT, GSFPLT and CONVU, other auxiliary operations to handle the experimental data are necessary and for these specific purposes the other four programs have been developed. RVPUN allows one to produce a set of cards with the observed structure factor to which the magnitude of the reciprocal vector has been added. TFCNV makes it possible to convert the temperature factors given in conventional form (Debye-Waller factors) into proper Gaussian constants which include the temperature effect and the form factor of the shell. DIFTAP makes it possible to plot difference electron density maps between the SES and convolution values of the electron density. PFPLT produces a plot of the atomic coordinates in the unit cell of the crystal in study, allowing one to compare those positions with the electron density maps. Finally, ADDATA was developed to create a single storage for the observed structure factors of all crystals under study in the Materials Science Laboratory to be analyzed by the SES method.

All the calculations were performed in an IBM 7044 computer and the drawings were plotted from an IBM 7044 generated tape with a 470 CalComp off-line magnetic tape unit equipped with a 565 CalComp digital plotter existing in the Materials Science Laboratory.

Acknowledgment

We wish to acknowledge the facilities given to this project by the Data Processing and Computing Center, Southern Illinois University. This research was partially supported by the Solid State Sciences Division of the Air Force Office of Scientific Research, Grants AF-AFOSR 832-67 and AF-AFOSR 68-1587.

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INSECTICIDE RESIDUE LEVELS IN EGGS OF WILD PHEASANTS IN ILLINOIS

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Illinois Natural History Survey, Urbana

ABSTRACT. — Residues of both aldrin and DDT were found in 119 of 120 eggs from 21 clutches of eggs of wild pheasants (*Phasianus colchicus*) in east-central Illinois in 1966; heptachlor residues were detected in 61 of the 120 eggs. Averages and maximum residue levels observed were, for dieldrin, 0.30±0.08 ppm and 2.82 ppm, and for p,p′-DDE, 0.15±0.02 ppm and 0.61 ppm, as determined for wet weight of entire egg contents. The maximum level of heptachlor epoxide observed was 0.40 ppm. Although average values for individual pesticides appeared within the "safe" range, analysis revealed high variability in residue levels both among eggs and among clutches of eggs. These findings suggest a widespread contamination of the pheasants' environment in this area by persistent residues of chlorinated hydrocarbon insecticides.

Our purpose is to report levels of three common chlorinated hydrocarbon insectcide residues (dieldrin, p, p′-DDE, and heptachlor epoxide) in the eggs of wild pheasants, collected in 1966 in Champaign, Ford, Livingston, and McLean counties, east-central Illinois. The population sampled occurs on an intensively cultivated region dominated by cash-grain farming. In 1966 corn and soybeans occupied 46 and 27 percent, respectively, of the total land area of the counties in which the eggs were collected (Illinois Cooperative Crop Reporting Service 1967:6-8).

From 1964 through 1966, about half of the corn acreage in Illinois was treated with aldrin, most commonly in granular form. Aldrin was typically either broadcast on and disked into the soil or applied directly in the row at planting, at a rate of 1 to 1½ lb technical material per acre, to control injurious insects in the larval stage (H. B. Petty, Illinois Natural History Survey, Urbana, unpublished data). The period of aldrin application (May) coincides with the seasonal peak of pheasant egg-laying. Once ingested, aldrin is readily converted into its epoxide, dieldrin, by metabolic activity (Bann et al. 1956:939).

In Illinois, the present trend is toward decreasing use of aldrin in the production of corn. The amounts applied in 1967 and 1968 were, respectively, about 5 percent and 25 percent less than in 1966 (H. B. Petty, Illinois Natural History Survey, Urbana, unpublished data). Aldrin is being replaced by the organo-phosphates because of the rapid spread of strains of corn rootworms (*Diabrotica* spp.) and a complex of other root-feeding insects resistant to aldrin. Nevertheless, we feel it is important to make this report because (1) large quantities of aldrin have been applied to pheasant habitat over much of the pheasant range, and this material will persist in the environment in its epoxide form, dieldrin, for many years, and (2) we anticipate

continued extensive use of aldrin on the basis of its past record and the promotional activities of its manufacturer.

The use of heptachlor paralleled that of aldrin, but heptachlor made up only about 20 percent of the total quantity of chlorinated hydrocarbon insecticides used in Illinois agriculture during the middle 1960's (Stevenson Moore III, Illinois Natural History Survey, Urbana, unpublished data).

The use of DDT in Illinois agriculture was widespread from the late 1940's through the midde 1950's, reaching a peak in 1956 and declining rapidly thereafter as DDT was phased out in favor of other chemicals. DDT has not been used extensively in Illinois agriculture since the late 1950's (Stevenson Moore III, Illinois Natural History Survey, Urbana, unpublished data).

Methods

Pheasant eggs were collected during June, 1966, from hayfields at the time of mowing. One hundred twenty-two eggs, representing 21 individual clutches, were obtained. The eggs were labeled, placed individually in polyethylene bags, and frozen until they could be analyzed. All eggs were analyzed individually except for 1 clutch of 2 eggs that was pooled.

Although chlorinated hydrocarbon insecticide residues are concentrated in the lipids of the yolk (Lamb et al. 1967:25), our determinations of residue levels were based on the wet weights of the entire contents of whole eggs after their shells and the associated membranes were removed. This method was followed because the incubation status of the eggs was variable and we had no knowledge of any possible effect of incubation on residues or moisture in the remaining yolk. Our method differs from that of several workers (Baxter et al. 1969:100, as described by R. L. Linder, personal communication, 3/14/69; Atkins and Linder 1967:747; and Lamb et al. 1967:25), who presented data based on the wet weight of the yolk alone, but is the same as that of Labisky and Lutz (1967:16).

To facilitate comparison of data obtained during this study with data of Lamb et al. (1967), Atkins and Linder (1967:747), and Baxter et al. (1969:100), their data were converted by multiplying with a factor of 0.406. This factor is based on the average composition, by weight, of eggs of ring-necked pheasants, as reported by Romanoff and Romanoff (1949:114).

Individual eggs were prepared for chromatographic analysis by saponification in alcoholic potassium hydroxide and by acetonitrile partitioning (Burchfield et al. 1965). Alkaline digestion does not affect aldrin and dieldrin. DDT is converted to DDE; heptachlor epoxide is stable if not heated (W. N. Bruce, Illinois Natural History Survey, Urbana, personal communication, 8/13/69). Each specimen was analyzed by gas chromatography (Beckman model GC-4), utilizing an electron capture detector. Approximately 12 different stainless steel columns, 3 to 4 feet long, with an inside diameter of 1/16 inch, packed with 1 percent Shell EPON resin 1001 and 0.5 percent DuPont Viton A fluoroelastomer

on a solid support of Varian Aerograph Chromosorb W, AW-DMCS, 100/120 mesh, were used to make these analyses. Gas flow rates were 40 cc/minute for the carrier helium, 75 cc/minute for the discharge helium, and 2 to 5 cc/minute for the carbon dioxide. The inlet line was operated at 210 C, the column at 180 (to 220) C, the detector line at 237 C, and the detector at 247 C. Retention times with the column at 180 C were felt to be excessive, and were often reduced (at the expense of column life) by increasing the column temperature to 220 C.

Relative retention times of aldrin, heptachlor epoxide, p,p′-DDE, and dieldrin were, respectively, 2.0, 6.1, 8.8, and 11.5, permitting proper identification and quantification of each of these insecticides. Because wide variations occurred in the lower limits of detection of heptachlor epoxide, no attempt was made to estimate the mean value, and incidence must be considered a minimum figure.

As a basis for estimating residues, standards were analyzed with every specimen. Measurements were double- or triple-replicated for each sample; residues were estimated to the nearest 0.01 ppm (micrograms of insecticide per gram of egg contents, wet weight). In addition, several interlaboratory check samples were analyzed and confirmed by Dr. W. N. Bruce and his associates in the Section of Economic Entomology, Illinois Natural History Survey, Urbana. Determinations were not verified by paper or thin-layer chromatography.

Percent recovery tests indicated a range of 80 to 110 percent. Data presented in this report do not include a correction factor for percent recovery.

Results

Residues of both aldrin/dieldrin and DDT were detected in 119 of 120 eggs analyzed individually and in each of 20 clutches (Tables 1 and 2). In addition, residues of heptachlor were observed in 61 of the 120 eggs and in 15 of 20 clutches (Table 3). These incidence figures represent a minimum accounting because the incidence of heptachlor residues at levels below 0.1 ppm is not adequately represented and because no attempt was made to account for lindane, chlordane, endrin, and for metabolites and isomers of DDT other than p,p′-DDE.

Mean (with 95 percent confidence limits) residue levels observed per egg (120 eggs) were, for dieldrin, 0.30 ± 0.08 ppm, and for p,p′-DDE, 0.15 ± 0.02 ppm, as determined for wet weight of entire egg contents.

Considerable variation in residue levels was evident within individual clutches as well as among clutches of the entire sample of 21 clutches (Tables 1-5). Although our sample was small and contained few complete clutches, the data show, as one might expect, that variability was less within individual clutches than it was over the entire sample (Table 4). In general, for clutches having high average residue levels, all eggs tended to be relatively high, and vice versa. Analysis of variance verified that significant differences ($F_{3,46} = 10.19$) existed in dieldrin levels among the four clutches compared.

TABLE 1.—Levels of dieldrin (ppm wet weight) in contents of eggs of wild pheasants, collected in east-central Illinois in June, 1966.

	Clutch Reference Number											
	45A	45B	94	57	100	101	105	123	124	125	126	127
County	Liv.	Liv.	Ford	Liv.	Ford	Cham.	Cham.	McL.	Cham.	McL.	Ford	Ford
No. eggs in clutch	NK[1]	NK	NK	11	8	17	NK	8	NK	13	11	NK
No. eggs analyzed	1	3	2	2	1	17	3	2	8	11	11	9
Incubation (days)	0[1]	14	NK	10	8	20	18	16	19	7	21	15
Mean dieldrin	0.14	0.44	0.03	2.33	0.04	0.31	0.42	0.14	1.55	0.47	0.05	0.26
Dieldrin in eggs	0.14[2]	0.52 0.50 0.30	0.03 0.03	Pooled	0.04	0.26 0.24 0.26 0.33[8] 0.38[8] 0.43 0.25 0.24 0.40[9] 0.21 0.38 0.39 0.42 0.29 0.23 0.14 0.42[9]	0.66 0.04[9] 0.57[9]	0.19 0.10	1.92 1.75 1.54 2.82 2.20 0.63[4] 1.04 0.49	0.23[7] 0.42 0.24 0.31 0.33 1.53 0.34 0.20 0.35 0.15[7] 1.12	0.03[3] 0.06 0.05 0.03 0.01 0.07 0.04 0.02 0.02 0.13 0.06	0.15 0.66 0.22 0.26 0.19 0.22[6] 0.35[5] 0.19[5] 0.13

TABLE 1.—(Cont.)

	Clutch Reference Number								
	128	130	134	136	137	153	154	155	158
County	Liv.	McL.	McL.	Cham.	Cham.	Liv.	Liv.	Ford	Liv.
No. eggs in clutch	11	5[1]	NK	NK	NK	NK	NK[1]	NK[1]	12
No. eggs analyzed	7	5	6	9	5	6	2	1	11
Incubation (days)	18	0[1]	8	NK	NK	NK	0[1]	0[1]	12
Mean dieldrin	0.27	0.04	0.15	0.16	0.13	0.22	0.06	0.02	0.08
Dieldrin in eggs	0.17	0.02[2]	0.17	0.07	0.16	0.12	0.07	0.02[2]	0.09
	0.13	0.02	0.16	0.07	0.12	0.12	0.05		0.10
	0.32	0.11	0.11	0.16	0.04	0.68			0.09
	0.16	ND	0.21	0.07	0.16	0.06			0.13
	0.53	0.04	0.16	0.11	0.19	0.18			0.06
	0.52		0.10	0.67		0.15			0.06
	0.09			0.09					0.08
				0.16					0.09
				0.06					0.10
									0.06
									0.06

NK = not known.
ND = not detected (less than 0.004 ppm).
1. Clutch incomplete: hen still laying. 2. Egg in oviduct. 3. Hatchling: 4. Embryo dead. 5. Embryo dead and decomposed. 6. Embryo dead at 1 day. 7. Embbryo dead at 2 days. 8. Embryo dead at 8 days. 9. Embryo at 14 days.

TABLE 2.—Levels of p,p′-DDE (ppm wet weight) in contents of eggs of wold pheasants, collected in east-central Illinois in June, 1966.

	Clutch Reference Number											
	45A	45B	94	95	100	101	105	123	124	125	126	127
County	Liv.	Liv.	Ford	Liv.	Ford	Cham.	Cham.	McL.	Cham.	McL.	Ford	Ford
Mean p,p′-DDE	0.16	0.16	0.03	0.03	0.04	0.08	0.06	0.23	0.27	0.41	0.09	0.23
Individual eggs	0.16[2]	0.18	0.03	Pooled	0.04	0.09	0.11	0.20	0.31	0.42[7]	0.03[3]	0.13
		0.19	0.03			0.08	Trace[9]	0.26	0.53	0.42	0.09	0.24
		0.12				0.09	0.06[9]		0.26	0.35	0.10	0.15
						0.08[8]			0.43	0.47	0.08	0.20
						0.07[8]			0.26	0.45	0.04	0.56
						0.09			0.18[4]	0.61	0.08	0.22[6]
						0.06			0.10	0.43	0.08	0.08[5]
						0.06			0.07	0.33	0.06	0.10[5]
						0.08[9]				0.35	0.08	0.40
						0.07				0.45[7]	0.22	
						0.15				0.27	0.13	
						0.08						
						0.08						
						ND						
						0.13						
						0.07						
						0.08[9]						

TABLE 2.—(Cont.)

	Clutch Reference Number								
	128	130	134	136	137	153	154	155	158
County	Liv.	McL.	McL.	Cham.	Cham.	Liv.	Liv.	Ford	Liv.
Mean p,p′-DDE	0.12	0.04	0.11	0.12	0.09	0.07	0.06	0.22	0.10
Individual eggs	0.06	0.02[2]	0.03	0.04	0.08	0.02	0.06	0.22[2]	0.17
	0.05	0.02	0.22	0.07	0.12	0.12	0.05		0.14
	0.10	0.11	0.11	0.16	0.04	0.15			0.08
	0.07	0.01	0.12	0.04	0.12	0.02			0.13
	0.21	0.04	0.11	0.04	0.08	0.10			0.09
	0.26		0.09	0.50		0.03			0.06
	0.09			0.08					0.13
				0.12					0.05
				0.07					0.10
									0.08
									0.09

Trace = detected at level below 0.01 ppm.
ND = not detected (less than 0.08 ppm).
See Table 1 for explanation of superscripts.

TABLE 3.—Levels of heptachlor epoxide (ppm wet weight) in contents of eggs of wild pheasants, collected in east-central Illinois in June, 1966.

	Clutch Reference Number											
	45A	45B	94	95	100	101	105	123	124	125	126	127
County	Liv.	Liv.	Ford	Liv.	Ford	Cham.	Cham.	McL.	Cham.	McL.	Ford	Ford
Mean heptachlor epoxide	0.19	ND	0.01	0.03	0.01	ND	0.15	ND	0.21	0.05	ND	0.02
Individual eggs	0.19[2]	ND	0.02	Pooled	0.01	ND	0.40	ND	0.27	0.08[7]	ND[3]	0.04
		ND	ND			ND	ND[9]	ND	0.26	0.04	ND	0.03
		ND				ND	0.06[9]		0.26	0.03	ND	0.03
						ND[8]			0.39	0.05	ND	0.03
						ND[8]			0.35	0.06	ND	ND
						ND			0.11[4]	0.05	ND	ND[6]
						ND			0.04	0.07	ND	ND[5]
						ND			0.02	0.06	ND	0.03[5]
						ND[9]				0.03	ND	0.01
						ND				0.08[7]	ND	
						ND				ND	ND	
						ND						
						ND						
						ND						
						ND						
						ND						
						ND[9]						

TABLE 3.—(Cont.)

	Clutch Reference Number								
	128	130	134	136	137	153	154	155	158
County	Liv.	McL.	McL.	Cham.	Cham.	Liv.	Liv.	Ford	Liv.
Mean heptachlor epoxide	0.10	Trace	ND	0.04	Trace	Trace	Trace	ND	0.03
Individual eggs	0.06	ND[2]	ND	0.04	ND	Trace	Trace	ND[2]	0.03
	0.03	ND	ND	0.02	ND	ND	Trace		0.01
	0.13	0.01	ND	0.08	0.01	ND			0.01
	0.07	ND	ND	0.04	ND	Trace			0.01
	0.12	ND	ND	0.04	ND	Trace			0.04
	0.26		ND	ND		0.01			ND
	0.04			0.05					0.01
				0.01					0.01
				0.04					0.10
									0.07
									ND

ND = not detected (less than 0.5 ppm).
Trace = detected at level below 0.01 ppm.
See Table 1 for explanation of superscripts.

TABLE 4.—Variation in dieldrin residues of clutches of eggs of wild pheasants from east-central Illinois, 1966.

	Clutch Reference Number				Sample of 20 Clutches
	126	158	101	125	
No. eggs in clutch	11	12	17	13	Not applicable
No. eggs examined	11	11	17	11	120
Range (ppm)	0.01–0.13	0.06–0.13	0.14–0.42	0.15–1.53	0.0–2.82
Mean (ppm)	0.05	0.08	0.31	0.47	0.30
Standard deviation	0.03	0.09	0.09	0.44	0.44
Coefficient of variation	0.60	1.13	0.29	0.94	1.46

TABLE 5.—Variation in p,p′-DDE residues of clutches of eggs of wild pheasants from east-central Illinois, 1966.

	Clutch Reference Number				Sample of 20 Clutches
	126	158	101	125	
No. eggs in clutch	11	12	17	13	Not applicable
No. eggs examined	11	11	17	11	50
Range (ppm)	0.03–0.22	0.05–0.17	ND–0.15	0.27–0.61	ND–0.61
Mean (ppm)	0.09	0.10	0.08	0.41	0.15
Standard deviation	0.05	0.04	0.03	0.09	0.13
Coefficient of variation	0.57	0.37	0.38	0.22	0.90

ND = not detected (less than 0.08 ppm).

DISCUSSION

It appears that in 1966 virtually every pheasant egg laid in the area of our collections contained residues of at least aldrin/dieldrin and DDT. In addition, about half the eggs apparently contained heptachlor residues. Considering the history of widespread use of insecticides in Illinois agriculture (H. B. Petty and Stevenson Moore III, Illinois Natural History Survey, Urbana, unpublished data), this condition undoubtedly extended well beyond the area sampled.

These data provide a limited picture of the occurrence of three chlorinated hydrocarbon residues in the eggs of wild pheasants, but they do not define the role of such insecticides as a factor in the ecology of that population. We have no knowledge of what residue levels in the ranges observed implies in terms of physiological status of the wild hens that laid them or in the chicks they might produce. If residue levels do reflect a problem or a potential problem, as we suspect, we do not yet know its parameters or the

trends in its magnitude. The incidences of aldrin/dieldrin, DDT, and heptachlor residues, however, leave little doubt that the pheasants' environment in east-central Illinois in 1966 had been extensively contaminated by these persistent insecticides.

The average levels of contamination for our sample were approximately 10 times the mean level of 0.03 ppm (after conversion) for dieldrin and 15 times the mean level of 0.01 ppm (after conversion) for DDE found in a sample of wild pheasant eggs from southeastern South Dakota in 1967 (Baxter et al. 1969:100). Although no error terms which would facilitate comparisons were given for the South Dakota samples, it appears that the eggs in our sample contained more dieldrin and DDE than did the eggs of wild pheasants from South Dakota in 1967.

The highest residue levels observed in eggs in our Illinois sample were 2.82 ppm dieldrin, 0.61 ppm DDE, and 0.40 ppm heptachlor epoxide. These levels were, respectively, about 5, 20, and 4 times the maximum levels observed by Baxter et al. (1969:100) in eggs from the South Dakota sample (0.59 ppm dieldrin, 0.03 ppm DDE, and 0.10 ppm heptachlor epoxide, after conversion).

The dieldrin levels we observed were lower than those reported by Labisky and Lutz (1967:16) who found 4.60, 4.96, and 7.91 ppm dieldrin in three samples each comprised of two eggs from nests of wild pheasants in an area near Donovan, Illinois, that was subjected to an aerial, solid block application of aldrin at a rate of 2 lb technical material per acre in April, 1960, to contain an infestation of Japanese beetles (*Popillia japonica*). It was their conclusion (1967:23) that, after treatment of the area, pheasants suffered "a substantial mortality from acute poisoning and a lowered reproductive efficiency from chronic poisoning." The high concentrations of dieldrin that they observed, in comparison with our findings, are believed to reflect the more extensive nature of the treatment, the lack of immediate incorporation of the toxicant into the soil, the timing of the application (April rather than May), or some combination of these factors.

Responses reported for caged pheasants fed standardized dosages of dieldrin offer a clue to the possible responses of wild pheasants to that poison. However, interpretation must be undertaken with caution, as other factors may have influenced the respective responses. Atkins and Linder (1967:752) reported that average levels of dieldrin residues in the eggs of pheasants fed 2, 4, and 6 mg of dieldrin per week for 12 weeks were (after our conversion of their data): 3.2, 7.5, and 13.6 ppm, respectively. These averages were considerably higher than those detected in our sample but, except for the 6 mg group, they were in the same general range as those reported by Labisky and Lutz (1967:16). Atkins and Linder (1967:752) concluded that parameters of reproduction were not adversely affected in hens in the 2 and 4 mg treatment classes but that condition (body weight) was lowered and egg production reduced in the 6 mg class. The highest level of dieldrin residues observed in any egg of our sample was also lower than the mean content

of dieldrin in eggs from hens in the 2 mg class.

Conclusion

Thus, at first glance, it appears that the average level of dieldrin residues in our sample was within the "safe" range. But average values for individual toxicants are poor yardsticks because they fail to recognize the degree of variation from the norm expressed by individuals. In our sample, the more contaminated eggs contained 5 to 10 times the average level of dieldrin. Consideration of average levels of individual insecticides tends to obscure the total degree of contamination and the fact that several toxicants in combination can be more lethal than one alone (Chemical and Engineering News 1966:19). Also of potential significance is the finding of Baxter et al. (1969:96) that reproductive parameters were significantly reduced in groups of penned pheasants when second-generation hens had received dieldrin via the egg.

It appears that, in Illinois, the use of the long-persistent chlorinated hydrocarbons, particularly aldrin, DDT, and heptachlor will continue to be reduced in favor of more toxic but less stable compounds. We are hopeful that the long-term effect of this change will be potentially less severe on wildlife than the possible effects of continued application of high levels of the chlorinated hydrocarbons.

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TAURINE IN DYSTROPHIC MOUSE MUSCLE

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ABSTRACT. — Taurine concentrations in the rear leg muscles of eight-week-old male mice were compared for normal and hereditarily dystrophic animals. Normal concentrations were determined and found to be higher than previously reported for rats. The taurine concentration found in the dystrophic animal was not significantly different from that found in the normal animal, in contrast with similar experiments involving chickens.

A remarkable increase in the concentration of free taurine (2-aminoethanesulfonic) acid has been found in the dystrophic muscles of chickens (Peterson, 1963). Furthermore, a correlation between severity of the dystrophy and the free taurine concentration has been demonstrated (Peterson, 1965). Because its concentration in normal tissues has an extensive range (Jacobsen, 1968) and muscle injury usually results in excessive elimination (Goyer, 1967) without appreciable alteration of the tissue concentration (Abe, 1968), taurine accumulation in muscle tissue is not considered to be directly responsible for muscular dystrophy. However, if one assumes that the taurine was produced in abnormal amounts from a vital metabolite, such as Coenzyme A (CoA), an interesting relationship can be developed.

The concentration of CoA has been shown to be decreased in cases of both nutritionally induced (Bieri, 1963) and hereditary muscular dystrophy (Radu, 1968). Decreased levels of CoA would be expected to have far reaching effects on muscle metabolism, among which would be altered lipid and energy metabolism. Both have been shown to be factors in muscular dystrophy (Meier, 1967; Olson, 1968). If taurine were produced by an oxidation of the functional portion of CoA, then loss of CoA would produce an increase in taurine. In itself, this has important ramifications for muscle intergrity. Welty and Read (1964) have shown that taurine alters membrane permeability, long recognized as characteristic of muscular dystrophy (Hazelwood, 1968).

Complicating factors in studies of muscular dystrophy are its diversity of form and its variation from species to species. While taurine concentrations are increased and CoA decreased (unpublished results) in dystrophic chicken muscle, a step preliminary to testing a general hypothesis requires comparison of normal and dystrophic mouse muscle to determine if taurine accumulation is characteristic of muscular dystrophy in this animal. Free taurine in normal mouse muscle, not previously reported, must also be determined.

Methods and Materials

A total of sixteen mice obtained from Jackson Laboratories, Bar Harbor, Maine, were used in this study. Six dystrophic animals of the strain 129B6F$_1$/J-dy were compared to six normal littermates and four normal animals of the closedly related strain, C57BL/6J. The rear leg musculature was obtained from the frozen carcass after ether anethesia, decapitation, and quick freezing on a block of dry ice. The tissue was homogenized by a Model S125 Bronson Sonifier at half maximum power in short bursts for a total period of five minutes. Free amino acids were extracted from the deprotenized homogenate by the method of Awapara (1953). The final extract was passed through a 62 x 1.3 cm column of Dowex 50W-X2 (acid form), using a 0.2 N citrate buffer at pH 3.1 as elutant to affect a separation of amino acids (Moore and Stein, 1954). Taurine was monitored in the column fractions by thin-layer chromatography on cellulose plates using a solvent of methanol:water:pyridine (80:20:4 v/v/v). Detection was by ninhydrin spray. Fractions containing taurine were assayed by the colorimetric ninhydrin method of Rosen (1957). Parts of the extracts were then pooled and submitted for analysis on an automatic amino acid analyser in the Northern Utilization Research and Development Laboratories of the U. S. Department of Agriculture.

Results and Discussion

Taurine concentration determined in our laboratories, reported in Table 1, is expressed as μ moles per gram wet tissue. Because the amount of fat in the animals appeared to be minimal, it seemed unnecessary to report on a fat-free basis. The large increases in taurine previously reported for dystrophic muscle appears not to occur in dystrophic mouse muscle. On the contrary, small but insignificant decreases in the free taurine of dystrophic mouse muscle are observed. Data from automatic amino acid analyses are tabulated in Table 2. Again, the taurine concentration of the dystrophic muscle is slightly lower than that of the normal litter-

Table 1.—Taurine Concentration in Normal and Dystrophic Leg Muscle of Mice[1] (μ mole/g wet tissue).

Tissue	*Trial 1*	*Trial 2*	
Normal - 1	30.46	33.49	
Normal - 2	26.86	25.17	
Normal - 3	24.28	25.21	
Average	27.20	27.96	
Overall Average			27.58
Dystrophic - 1	20.89	21.06	
Dystrophic - 2	26.45	27.52	
Dystrophic - 3	20.62	17.90	
Average	22.65	22.16	
Overall Average			22.41

[1] Each sample represents two animals

Table 2.—Taurine in Leg Muscle of Normal and Dystrophic Mice Determined By Automatic Amino Acid Analyser (μ moles/g wet tissue).

Sample	Description	Taurine
I	Four Normal Animals C57BL/6J	23.88
II	Combination of Normal 1 & 2	28.65
III	Combination of Normal 2 & 3	20.31
IV	Dystrophic 1	19.32
V	Dystrophic 2	22.32
VI	Dystrophic 3	17.79

mates. In addition, the strain C57-BL/6J produces muscle taurine concentrations comparable to those observed in littermates of the dystrophic animals. Thus, it would appear that the reported concentrations are not peculiar to the strain of mice which carry the mutant gene. In any case, the taurine concentrations are higher than had been anticipated from reports of taurine in the rat and rabbit (Jacobsen, 1968). Normal concentrations of free taurine in the muscle of eight-week-old male mice must be in the range of 20-30 μmoles taurine per gram wet tissue.

It has been demonstrated that rat muscle maintains its normal compliment of free taurine even in the face of severe trauma (Abe, 1968). Consequently, measurement of taurine excretion must be determined prior to drawing conclusions about taurine production in these mice. Published reports (Hurley, 1955; Berger, 1962) are somewhat contradictory, but in humans, increases in excreted taurine are reported to accompany some cases of muscular dystrophy.

The accumulation of taurine in the muscle of dystrophic chicken does not occur in the muscle of the dystrophic mouse. Therefore, this is not a parameter characteristic of the diseased state in all species, and increased concentrations of taurine cannot be responsible for muscular dystrophy in the mouse. An involvement of CoA in this disease cannot be eliminated by these experiments since CoA can be decreased in either of two ways—by possible oxidation to taurine and by inhibited biosynthesis. That is, nutritional and hereditary dystrophies producing large amounts of taurine could result from excessive oxidation of CoA, whereas, hereditary dystrophy not yielding large amounts of taurine could result from insufficient CoA systhesis.

Acknowledgments

We wish to express our gratitude to the Illinois State Academy of Science for partial support of this project and to the Northern Utilization Research and Development Division of the U. S. Department of Agriculture for their kind assistance with analyses.

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THE MARIJUANA THRIPS, *OXYTHRIPS CANNABENSIS*, A NEW RECORD FOR ILLINOIS AND NORTH AMERICA

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ABSTRACT. — *Oxythrips cannabensis* Knechtel, host-specific to marijuana (*Cannabis setiva* L.), is newly recorded and redescribed from Illinois. Previously this thrips was known only from Siberia and Europe.

In cooperation with Dr. Alan W. Haney, Botany Department, University of Illinois, one of the authors (J. R. DeWitt) began a survey, in July 1969, of the insects associated with marijuana as part of a larger project involving the total ecology of this introduced plant. During his investigations he discovered the marijuana thrips, *Oxythrips cannabensis* Knechtel, previously unknown in Illinois and North America. In the remainder of the summer of 1969 numerous additional adult and larval specimens of *cannabensis* were taken from marijuana using berelese funnels and a wash technique. Some fewer specimens of *Frankliniella tritici* Fitch and *Thrips tabaci* Lindeman were also obtained by these methods.

Apparently *O. cannabensis* is host-specific to marijuana, or soft hemp, (*Cannabis sativa* Linneaus) as it has been rarely reported from other plants. This thrips was first described by Knechtel in 1923 from Rumania and later reported from Siberia (John in Priesner 1926). A Czechoslovakian generic record (Pillich 1914) was thought by Priesner (1926) to be the same species. Heretofore, these Palaearctic records constituted the known distribution.

The first Illinois specimens were discovered on the terminal parts of plants brought in from a large field of marijuana growing on the City of Urbana Sanitary Disposal grounds. Except for those taken by the Berlese method, plant sections were collected in plastic bags, washed in the laboratory by shaking in a weak solution of detergent water, after which the residue was filtered over a finely meshed silk cloth and then placed in 70% ETOH and examined. This wash technique, perfected by Mr. Thomas H. Wilson, Natural History Survey, for recovering thrips from soybeans, has proved to be of value in collecting many previously overlooked thrips and other small insects on various plants, particularly those with hairy leaves.

A redescription (the first in English) and new illustrations of this insect follow.

Oxythrips cannabensis Knechtel

Oxythrips cannabensis Knechtel (1923: 74). ♀. Type locality not given but either Chisinău (Bessarabia) or Misil (Buzău), Rumania. ♂, larva II described by Priesner (1926).

Female (macropterous).—Length 1.6 mm. General body color yellow, legs lighter yellow. Abdominal ter-

gites IX and X reddish yellow becoming brown at extreme apex of X. Antennal segments I pale yellow, II yellow clouded with brown, III to V light brown except pale at bases, VI to VIII brown. Ocellar pigment light brownish gray. Anterior lateral eye facets reddish yellow. Wings and body setae pale yellow.

Head as in Fig. 1, transversely striated. Major setae small. Ocelli placed in a fairly wide triangle. Mouth cone long and pointed. Maxillary palps each three-segmented; labial palps each two segmented, the basal segment minute. Antennal segments moderate in size, segments III and IV each with forked sense cone, style (segments VII and VIII) shorter than segment VI.

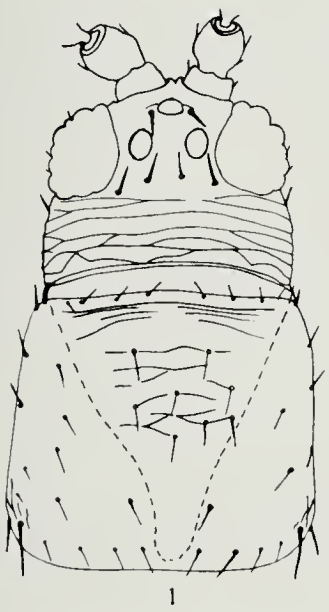

FIGURE 1. Female, head and prothorax, dorsal aspect.

Prothorax, Fig. 1, much longer than head with only the posterolateral pair of setae long, and with four pairs of smaller submarginal setae between each of the pair of posterolateral setae. Metascutum subreticulate medially. Forewings with venal setae moderately short, fore vein with three apical setae. Fore tarsi unarmed.

Abdomen with dorsal median setae not placed close together. Sternites II to VII each with several to 10 or more accessory median setae in addition to the usual three pairs of posterior setae. Abdominal tergite VIII lacking comb of setae. Tergite IX with the pair of setae anterior to the major dorsal pores reduced in size as is typical of genus, Fig. 2. Terminal segment (X) long and pointed, finely split dorsally.

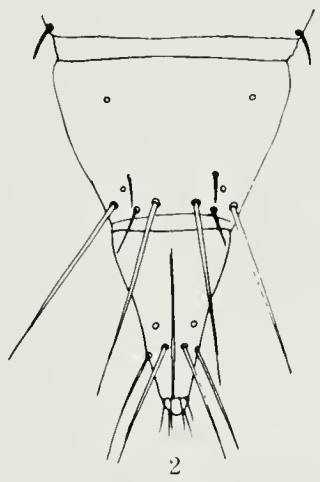

FIGURE 2. Female, abdominal tergites IX and X.

Male (macropterous). — Length about 1.3 mm. Similar to female except smaller and slightly paler yellow and with the following structural differences. Abdominal sternites III to VI each with a median, subanterior, nearly circular glandular area averaging about 8μ. Abdominal tergite IX with two pairs of median, thorn-like setae, the posterior pair being smaller and set farther apart than are the anterior pair, Fig. 3.

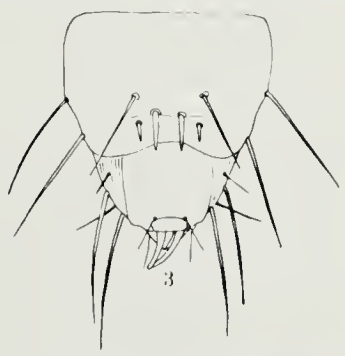

FIGURE 3. Male, abdominal tergites IX and X.

Larva I.—Length distended about 0.8 mm. Similar to larva II except smaller and slightly paler in color especially lighter brown on the antennae, head, pronotum and legs. Antennae each six-segmented, the annulations moderately strong. Body excrescences less prominent and much less numerous than as in larva II.

Chaetotaxy: Prothorax with 6 pairs of setae arranged as in larvae II, except lacking the posterolateral pair. Meso and metanotum each with four pairs of setae arranged in two rows of one pair anteriorily and three pairs posteriorily. Abdominal tergite I with two pairs of setae, tergites II to VIII each with three pairs of setae and corresponding sternites each with one pair of median setae. Abdominal segment IX, Fig. 5, with 2 pairs of dorsal setae and one pair of lateroventral setae (females); or with 2 pairs of dorsal setae, one pair of lateroventral setae and one pair of ventral setae (males). Abdominal segment X, Fig. 5, with 3 pairs of dorsal setae and one pair of ventral setae in both sexes.

Larva II.—Length distended about 1.4 mm. Body pale yellow with some brown patches. Apex and sides of head, spots on prothorax, legs except apical half of femur which is gray, and most of abdominal segment IX and X light brown. Antennal segment I, apex of II, and base and apex of III pale gray, remainder of segments brown. Body with much orange subintegumental pigment. Eyes crimson red. Setae hyaline.

Head, Fig. 4, shorter than prothorax, cheeks slightly constricted. Antennae each seven segmented. Pronotum with prominent apodemes

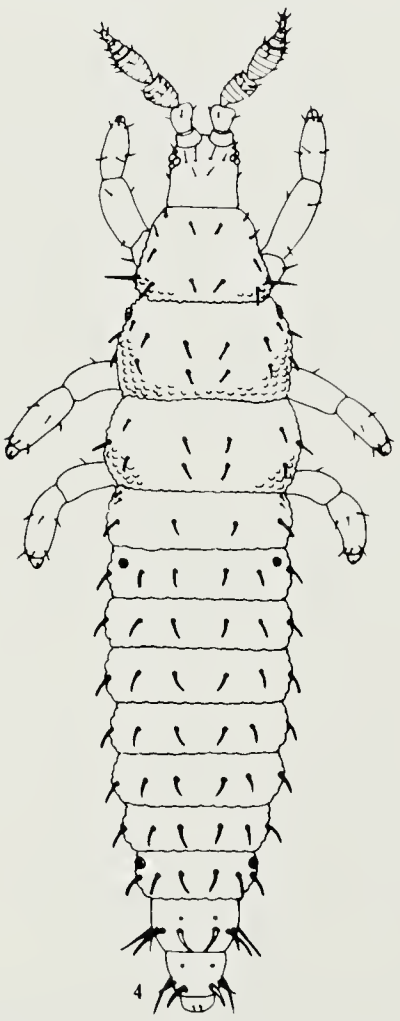

FIGURE 4. Larva II, dorsal aspect.

FIGURE 5. Larva I, terminal abdominal tergites.

running medio-posteriorly from the mid lateral margins. Head, anterior two-thirds of prothorax, and abdominal segments IX and X smooth, remainder of integument with simple raised excrescences, irregularly oval, larger dorsally than ventrally, arranged in six or seven more or less even rows dorsally and eight or nine rows ventrally. A pair of stigmatal plates each present on the anterolateral angles of the mesothorax and

on the lateral margins of abdominal tergites II and VIII.

Chaetotaxy: Head with a pair of preocular setae, two pairs of interocular setae, and one pair each of median and lateral postocular setae, all of which are pointed, as also are the antennal setae. Pronotum with seven pairs of peripheral setae, blunt to slightly knobbed, except posterolateral pair which is pointed and longest in size. Mesonotum with seven pairs of setae, arranged in two transverse rows of three pairs of blunt setae each and one minute pair of pointed setae just posterior to the spiracles. Metanotum with five pairs of blunt setae arranged in two transverse rows of two pairs each and one pair of midlateral setae. Setae on legs pointed.

Abdominal tergite I with two pairs of blunt setae arranged in a median transverse row and two pairs of minute, pointed setae on the anterolateral angles. Abdominal segments II to VIII dorsally each with three pairs of blunt setae arranged in a median transverse row and with a similar set of setae ventrally but these pointed. Abdominal segment IX, Fig. 6, with four pairs of pointed, dorsal setae arranged in a median transverse row, the median pair stoutest, with one pair of ventral setae in females, and two pair of ventral setae in males; segment X, Fig. 6, with three pairs of pointed, dorsal setae, the median pair stoutest, and with one ventral pair of setae, occasionally (abnormally) with two ventral setae.

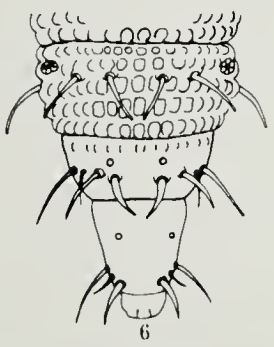

FIGURE 6. Larva II, terminal abdominal tergites.

The sexes in both larva I and II appear to be nearly equal in the samples examined. Priesner (1958) suggested that in the Thripidae in larva II 4 pairs of setae on abdominal segment IX represent females and those with 5 pairs represent males. In the larvae of *O. cannabensis,* the numbers of pairs of setae are one more than given by Priesner and we have presumed that those with the fewest setae likewise produce females, whereas those with the most produce males.

Pupae. — Unknown. Not present on host plant and presumed to occur in the surrounding soil.

Illinois records. — Collected from mid July to mid September 1969 in the following northern counties: ADAMS, BUREAU, CARROLL, CHAMPAIGN, HENRY, KNOX, LEE, LOGAN, MASON, PEORIA, ROCK ISLAND, STARK, AND WHITESIDE. Marijuana was not found in the southern part of the state and there are few records of its former presence there (Winterringer and Evers 1960).

The only other species of *Oxythrips* in Illinois is *O. divisus* Hood, which is found on yellow pine in the southwestern tip of the state. The species *divisus* can be separated from *cannabensis* by the shorter mouthcone, red ocellar pigmentation, darker antennal segments with III to VIII almost entirely brown, and by the fewer (one or two pairs only)

accessory setae on the abdominal sternites.

Acknowledgments

We wish to express our appreciation to Mr. Tim A. Cooley, Natural History Survey, for the carefully prepared slide mounts of the specimens studied and to Mr. John C. Marlin, Natural History Survey, for collecting many of these specimens.

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ENDOTHAL INDUCED MUTATIONS IN DROSOPHILA MELANOGASTER

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ABSTRACT. — Endothal, an herbicide and defoliant, known to have cytological effects on chromosomes, is found to be mutagenic for *Drosophila melanogaster*.

Endothal-3003 (Niagara Chemical Company) is an herbicide and a defoliant. It has been used in the past as a defoliant for cotton, corn, apples, and cherries to facilitate mechanical harvesting. The active ingredient is disodium-3,5-endoxohexahydrophththalate at a concentration of 19.2%.

The cytological effects of endothal on meristematic tissue have been investigated by Daniel (1952). Cytologically this compound has the following effects on pea root tip mitosis at doses as low as 0.1 part per million:

a. Moderate lowering of the mitotic index.
b. Clumping of metaphase, but not to an extent such as to prevent more or less normal anaphase separation.
c. Lagging or erratic movement of individual chromosomes relative to the main mass.
d. Translocations and possibly fragmentations.

Since the effects of this compound appeared to be largely on the chromosomes themselves rather than on the mechanisms, it is suggested that it might well be a mutagen.

METHODS AND MATERIALS

Oregon-R males of *Drosophila melanogaster* at an age of 24 hours or less were subjected to aerosol treatment with Endothal. An aeration chamber consisting of a 12″ glass tube ¾″ in diameter with a long strip of wet filter paper in it to prevent dessication was fitted with holed rubber stoppers and appropriate glass tubing, the ends of which were covered with cheese-cloth. The ''entrance'' end of the glass tubing passed to a ''bubble'' chamber containing the Endothal. Filtered laboratory air was passed through the Endothal in the ''bubble'' chamber from which the Endothal-saturated air was passed to the aeration chamber containing the flies. The chemical was used full strength (19.2% commercial). The flies were treated for 24 hours. A control group received the same treatment but without the Endothal. About 10% of the test flies died during treatment.

Each of 30 treated and 22 control flies was mated with a Muller-5 female in individual 4″ x 1″ clear plastic vials on corn meal-agar medium. Live yeast was omitted and twice as much Brewer's yeast was added. Brother-sister F-1 matings were performed using the same type vials and medium. The progeny

from the F-1 matings were examined for wild type males, the absence of which indicated the presence of a sex-linked, recessive lethal.

To determine site of the induced lethals, 10 females of the composition M-5/lethal were mated in single pairs with marker stock of the composition *sc,t,v,f,car/Y*. The F-1 were test-crossed and the progeny scored for cross-over classes. The medium used was corn meal-agar with live yeast added. All matings were carried out at 25 degrees centigrade.

Results

The results for sex-linked recessive lethals in the controls compares favorably with the normal expected spontaneous rate for Oregon-R of about 0.012-0.100%. The results for sex-linked recessive lethals in the treated flies show a mutation rate of about 8.5 times the spontaneous rate (Table 1.). Sub-lethals and visibles were not checked.

Table 1. The Occurrence of Sex-linked Recessive Lethals in Controls and from Aerosol Treatment of Adult Oregon-R Males of *Drosophila* with Endothal.

Experiment	No. of X-Chromosomes Tested	No. of Sex-linked Lethals	% of Sex-linked Lethals
Control	1633	1	0.061
Endothal	2863	15	0.524

Using standard mapping procedures, the 10 lethals so far checked occur at random along the entire length of the X chromosome, except that four of the lethals are located to the right of *carnation,* and to the left of the kinetochore, suggesting a mutation in the heterochromatin. To date the basis for these lethals has not been determined. Further investigations are being conducted in that respect. It would also be interesting to know at what stage in development these lethals were operating.

Discussion

It may be concluded from this preliminary investigation that Endothal is mutagenic. This has certain implications when one considers the use to which it has been put. Likewise, in view of the use of other defoliants in military operations, knowledge of its mutagenic effect takes on additional significance. An exact comparison of Endothal with other organic mutagens is not possible as modes of treatment, test stock used, and control rates vary, and since the present study did not include sub-lethals and visibles, an increase in the potency of Endothal as a mutagen might well be inherent.

It is difficult to compare the cytological effects of Endothal on mitosis and mutagenicity with other chemicals from the weak-to-moderate mutagen class as the cytological aspects of most other mutagens has not been investigated, although Mitomycin-C has been found to cause breaks and translocations in *Tradescantia,* and likewise has been found to increase the mutation rate in *Drosophila* (Mukherjee, 1965), thus apparently paralleling the effects of Endothal. An investigation to ascertain the correlation, if any, between the cytological effects on mitosis and the mu-

tagenicity of these classes of compounds would be fruitful.

Summary

Endothal, an herbicide and defoliant is known to have aberrant effects on chromosomes. This investigation indicates it is also a mutagenic agent for *Drosophila.* In view of the use of herbicides and defoliants by both the civilian and the military, its mutagenicity takes on added significance.

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THE MIGRATORY STATUS OF THE CARDINAL, *RICHMONDENA CARDINALIS CARDINALIS*, IN THE VICINITY OF CARBONDALE, ILLINOIS

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ABSTRACT. — From January, 1966, to January, 1968, the migratory status of the Cardinal, *Richmondena cardinalis*, was investigated in the vicinity of Carbondale, Illinois. The data from the study suggest that the species is nonmigratory in this region. Data from studies by others suggest that the species is probably sedentary over most of its range, possibly expressing some seasonal movement at the northern boundaries of its long-established range.

In southern Illinois, the Cardinal, *Richmondena cardinalis cardinalis*, is abundant throughout the year, but its migratory status in the area is problematical. Graber and Graber (1963) reported that in both 1907 and 1957 the population of Cardinals in the southern portion of Illinois in January was 2.1 times the June level, while the number of Cardinals in northern and central Illinois seemed to fall below the June level. They stated (P. 494) that "This hypothesized 'migration' of the cardinal presents a problem that needs investigation through banding." The aim of the present study was to investigate the possibility that there is a regular seasonal movement of migration of Cardinals from northern and central Illinois into southern Illinois. This would mean a movement into the area in the autumn and out again in the spring and would constitute a population increase during the winter months of about 2 times the summer level as Graber and Graber suggested. Studies by Laskey (1944), Hundley (1953) and others and my observations indicate that the young of the year disperse during the autumn, and that there is a tendency for some of the experienced breeders to wander during the winter nonbreeding period. If dispersal and not migration was occurring, then one would expect the population to fluctuate but not to increase sharply. This then is the tenet of this investigation, that if the population does not increase sharply, and if through marking, most of the dispersed birds can be found, then no migration has taken place.

Two years study on 22 acres neither substantiates nor refutes the fact that Cardinals may migrate, but problems about migrations and range expansions can be solved only by several studies conducted over a period of time. The purpose of this paper is to post the data along with the method in which it was taken, for the benefit of anyone interested.

METHOD OF STUDY

The study was conducted from January 1, 1966, to January 30, 1968, on a 22-acre plot near Carbondale, Illinois. The area was selected because it represented the brushy forest edge type of habitat the Cardinal usually inhabits. Twenty-six traps were placed on this study plot, each having a cone-type entrance and a rear door which could be left

open. The traps served as feeders when they could not be checked periodically. The bait was cracked corn.

The most direct approach to demonstrate a seasonal north-south movement of Cardinals would be to band birds in the south, and recapture them in the north. However, in view of the number of birds that would have to be marked and the size of the area which would have to be searched, this approach was not used. Two other approaches were attempted. The first was a monthly census to determine if the population did fluctuate between summer and winter; and the second was to color mark Cardinals to see if the same birds were present winter and summer.

Population estimates of small birds face several problems, conspicuousness of the birds not withstanding. Weather had a definite effect on the daily movements of the Cardinals. During the winter months the birds moved only a little in stormy weather, but moved about freely and were very conspicuous just prior to inclement weather. On fair days with little wind the birds moved for an hour or two in the morning, but then settled down and remained secluded most of the day. During these times marked birds could be found perching in predictable locations. The presence of these marked birds also revealed that some birds moved in pairs, some in groups of three to five of mixed sex, and that all gathered into flocks of 20 or more near temporarily abundant food sources.

The following procedure was used to try to account for the variation in the numbers of birds which were conspicuously observable. First, the number of birds seen while attending the traps was noted. Second, about an hour each day was spent observing the movement of marked birds from seclusion. If I spent less than the entire day in the field, for example, the morning and the last two hours before dark, an estimate was made at the end of each work period. Then, in view of the weather and the movement of known birds, an estimate was made of the average number of birds present that day. It was a subjective estimate, but I think that it accounted for the fluctuation in the number of birds observable at any one time. For example, during both winters, eight to ten marked birds were seen on the study plot often enough to be considered to have had a winter home range there. If on a clear calm morning only ten birds were seen, three or four of them would have been marked. If in the afternoon with rising wind velocity and the prospect of snow, 20 or more were seen foraging for food, eight or ten of them would have been marked. Therefore, the estimate for the day would have been 20. If on a day when the birds moved very little, no more than eight or ten were seen at any one time, but each time a little less than half of them were banded, and by the end of the day all or nearly all of the marked birds were seen at least once, then it was assumed that at least 20 Cardinals were present on that plot. In addition, I could find Cardinals perching in predictable locations, Cardinals which probably would have been overlooked. The ratio of a little less than half of the birds being banded

in each sighting remained fairly constant throughout the winter. After nesting had begun in May and the leaves on the trees made it difficult to observe the color bands, the number of singing males was used in addition to this method to census Cardinals.

Each bird was marked with three colored, plastic, coil bands; one on the left leg and two on the right leg. The bands were discernible from as far as 50 yards with either binocular field glasses or a spotting scope. The bands remained in place well and seemed not to hinder the bird's movement.

A preliminary study was conducted from January through March, 1966. During this time I tried different sizes of traps, various trap locations, and several bait. Twenty-six birds were marked. In April, May, and June, 1966, this plot was visited twice a week. The population was estimated during these visits, and attempts were made to locate marked birds as far as one-half mile from the study plot. These visits continued from July through September on a once a week basis. Beginning in October, 1966, and continuing through April, 1967, the study area was visited four times a week for as many as eight hours each visit. The presence of previously marked birds was noted, unmarked birds marked, and the population estimated.

In April, trapping ceased. Population estimates on the study plot continued, and again attempts were made within a radius of one-half mile from the plot to locate marked birds no longer on the plot. Visits continued once or twice a week throughout the summer to October. From October through January, 1968, the study plot was visited once or twice a week, the presence of marked birds noted, and the population estimated. No additional birds were marked during this time.

Results and Discussion

The population fluctuated annually from a high near 30 in the summer months to a low near 20 in the autumn months (Figure 1). That

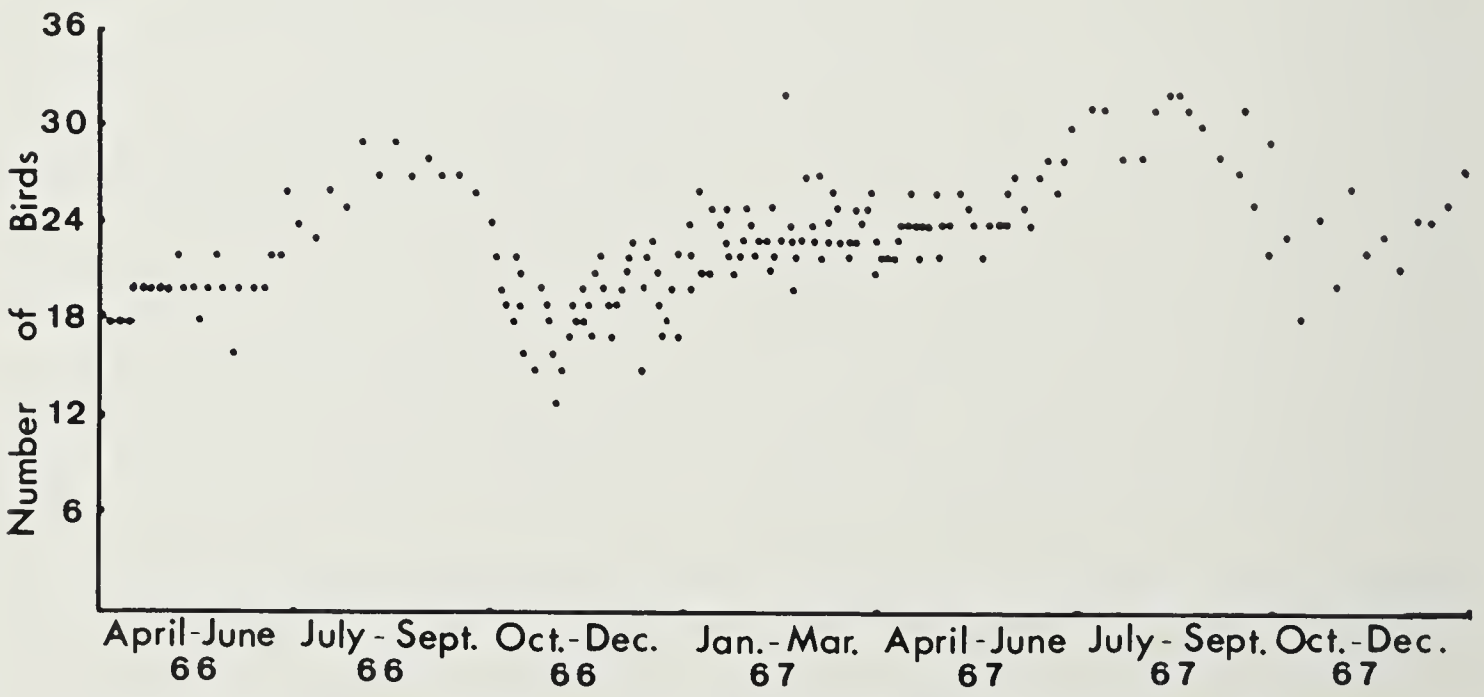

Figure 1. Population estimates on the study plot. Each dot indicates one estimation.

the months October and November were the lowest is not easily explained; one might expect these months to be the highest. Hundley (1953) described "molting shyness" during the months of September and October. I too noticed that during this period the Cardinals seemed shy. They sang little, and because leaves remain on many trees as late as the end of October in Carbondale, the birds were hard to find. However, if Cardinals had moved onto the study area during either winter, and moved off again in April or May to breed farther north, one would expect the winter population to be higher than the population at the onset of the breeding season. The population estimates from January, perhaps the coldest month in Illinois, to May, when the first nesting season for Cardinals is well under way in Carbondale varied only slightly (Figure 1). It would seem that this period, as much as any other period of the year, would show a marked population change if any significant winter influx and spring outflow occurred.

There is a possibility that the same number of Cardinals moved off, as moved onto the study area. However, of 13 males marked during the winter of 1966, at least 10 nested within one-half mile of the study plot the following spring (Figure 2). Of 31 marked males present during the winter of 1967, 21 were present within one-half mile of the study area the following spring (Figure 2). During the winter of 1968 no birds were marked, and only the banding plot, not the entire one-half mile radius, was searched. Ten of the 21 males present in the entire area during the spring of 1967 were found within the smaller area of the banding plot. Five of 13 females marked during the winter of 1966 were found the following spring, and 10 of 13 marked during 1967 were present in the vicinity the following spring (Figure 3).

Cardinals range as far as 1.8 miles in search of food during the winter (Hundley 1953). Scott (1967) reported that 35% of the breeding Cardinals he studied were missing from the study area the following year, and Lack (1954) showed an annual mortality rate of 40% to 60% for many songbirds. In the light of these figures on mortality and movement, I think that the number of birds remaining in the vicinity of the banding area the following spring during both years (1966 and 1967) indicated that the marked population was sedentary.

There is a possibility that Cardinals from northern and central Illinois were present in southern Illinois, but either they were on my study area but I did not capture any, or they were not on my study area at all. My observations indicated to me that experienced nesting pairs remained on or near their previous nesting site during the winter, whereas single birds tend to roam about more. This phenomena has been reported by Hundley (1953), Laskey (1944), and others. Being familiar with the area, they were extremely wary of a trap placed within their winter home range. In fact, about one-half of the wintering pairs on the study plot were never caught. I, of course, had no way of knowing whether unmarked pairs were plot winter residents or not, but judging

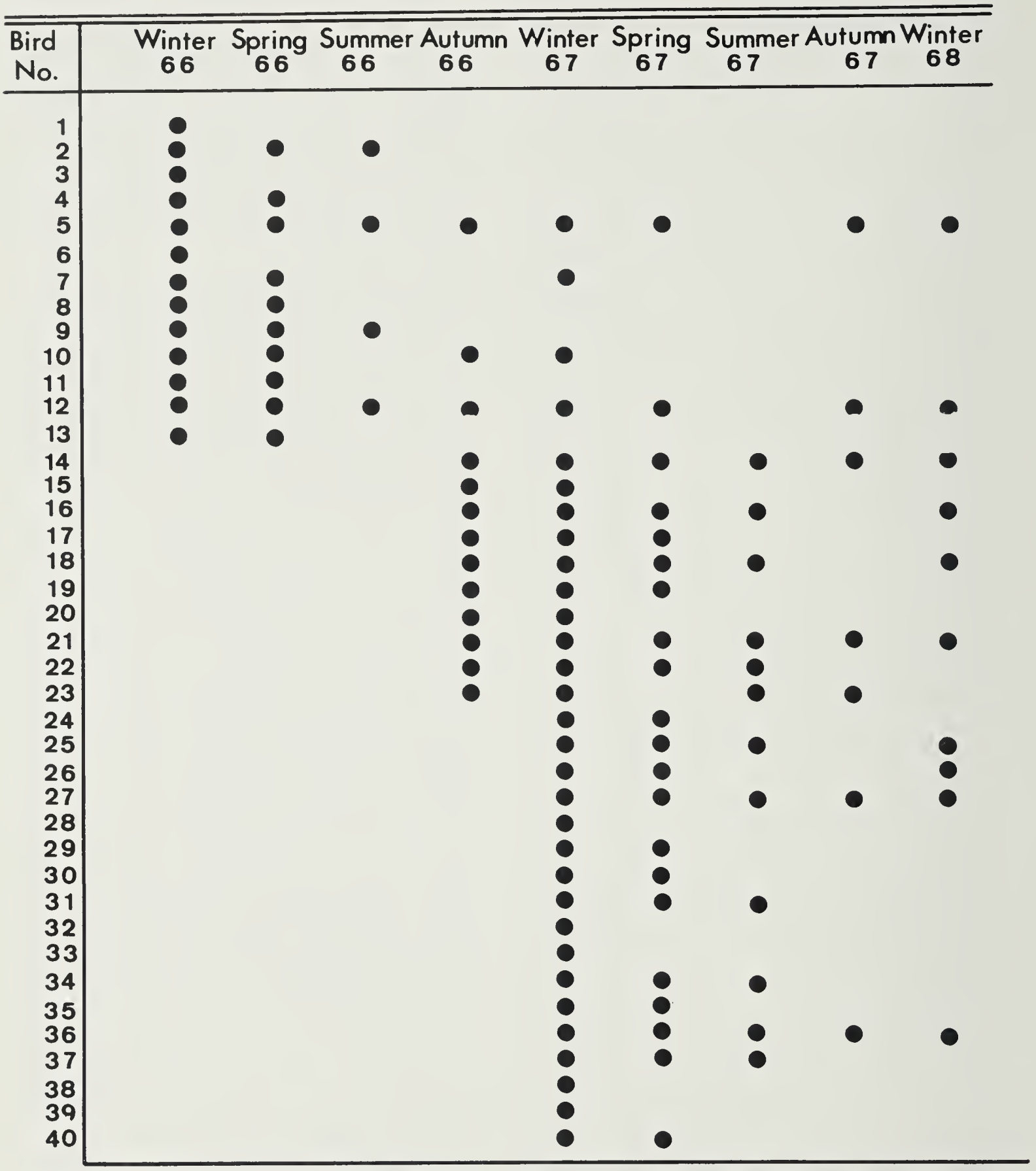

FIGURE 2. Observations of male Cardinals in the study area. The first dot indicates season of first capture, and succeeding ones indicate subsequent observations. (Spring, April-June; Summer, July-September; Autumn, October-December; Winter, January-March. Winter, 1968, January only.)

from my observations and those of others, these unmarked pairs were probably residents on or near to the study area. Marked pairs were extremely wary of a trap placed within their winter range, and were not often recaptured. Just prior to inclement weather I could catch 15 to 20 birds in a few hours, some of them more than once. Most always these Cardinals were never seen again until the following spring

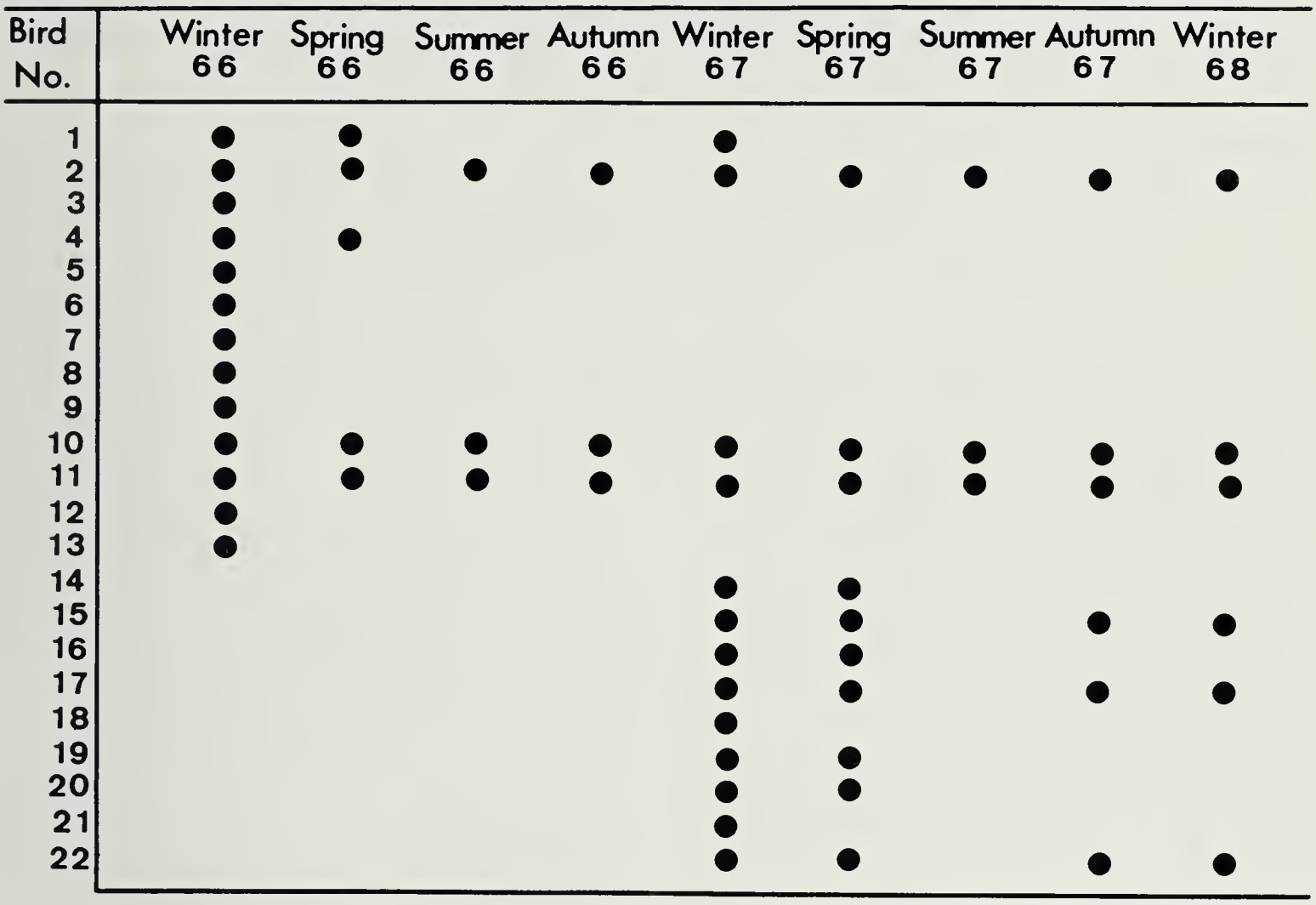

FIGURE 3. Observations of female Cardinals in the study area. The first dot indicates season of first capture, and succeeding ones indicate subsequent observations. (Spring, April-June; Summer, July-September; Autumn, October-December; Winter, January-March. Winter, 1968, January only.)

when they were found nesting or at least singing as far as one-half mile away. If they were seen or retrapped again, it was during another period of intensive feeding. It seemed to me than, that the resident birds were wary and difficult to catch, whereas a roaming bird was easily caught.

If it is true that a bird away from its area of greatest familiarity is most easily caught, my marked population should have had a high percentage of transitory visitors, and I should not have found as many as 70% of the males the following spring.

That there were migratory bands in southern Illinois, but not within the study area, is also a possibility. It would seem, however, that the presence of the Illinois Central Railroad within the study area, which provided a constant supply of grain dropped from passing cars, and my open traps, would have attracted any "migrating" Cardinals.

All of the reports of which I know indicating a movement of some type (Ridgway, 1881, Illinois; Talbot, 1902, Iowa; Sparks, 1913, Illinois; and Batts, 1955, Michigan) came from areas where the species was either extending its range or at the limit of its range. By contrast, those studies which concluded that the bird was sedentary (Laskey, 1944, Tennessee; Hundley, 1953, West Virginia; Burns, 1956, Michigan; Stewart and Robbins, 1958, central east

coast; Hendrick, 1967, Wisconsin; and Beddall, 1963, lower New England) were conducted well within the species long established range, as was this study.

Summary

Because: 1, the population did not rise sharply in the autumn and drop again in the spring, and 2, even though mortality rates for song birds have been reported to be as high as 40%, and Cardinals can wander as far as 1.8 miles, during either year about 70% of the marked males were located nesting within one-half mile from the place where marked the previous winter, this study suggests that in the vicinity of Carbondale, Illinois, the Cardinal is sedentary.

Acknowledgments

Data and procedures cited here are excerpts from a master of arts thesis for the Department of Zoology at Southern Illinois University, Carbondale, Illinois. I would like to thank Dr. Harvey I. Fisher for guidance throughout the study.

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PRELIMINARY REPORT ON FOSSIL PLANTS FROM THE CHESTER SERIES (UPPER MISSISSIPPIAN) OF ILLINOIS

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Abstract. — Numerous localities at various geological horizons in the Chester Series (Upper Mississippian) of southern Illinois have yielded a diverse flora preserved as extensive impressions, compressions including cuticle, and pyrite petrifactions. Included are: *Lepidodendron veltheimii*, *L. volkmannianum*, and *L.* sp. with attached foliage, *Lepidostrobus*, *Lepidostrobophyllum*, *Stigmaria ficoides*, *S. stellata*, *Archaeocalamites* including attached foliage and cones, *Fryopsis*, *Rhodea*, *Sphenopteris*, *Sphenopteridium*, *Adiantites*, *Botryopteris*, c.f. *Telangium*, *Rhynchogonium*, *Trigonocarpus*. This flora provides important floristic, morphological, and anatomical information about Upper Mississippian plants of North America.

Knowledge of Upper Mississippian vascular plants from North America is very incomplete. Most previous reports (Nóe, 1923; White, 1937a, 1937b; Bell, 1944; Read, 1955; Arnold and Sadlick, 1962) have dealt with small collections of rather fragmentary impressions-compressions. Well preserved compressions (Eggert and Taylor, 1968; Taylor and Eggert, 1968b) are still largely undescribed. The only previously described petrified plants from the North American Upper Mississippian have come from northwestern Arkansas (Mapes, 1966; Taylor and Eggert, 1967a, 1967b, 1968a).

Despite the presence of a well developed Upper Mississippian (Chesterian) stratigraphic sequence in Illinois, the published record of fossil plants in these rocks is scant. Early work by Lesquereux (1866; 1870) included a description of a few sandstone casts. Subsequently, Janssen (1940) restudied certain of Lesquereux's specimens, and made several revisions. Recently, Lacey and Eggert (1964) made further revisions based on Lesquereux's published figures and, after subsequent collecting, added four new taxa. The list of Chester plant from Illinois reported in these papers includes: *Lepidodendron volkmannianum, L. veltheimii, Stigmaria ficoides, S. stellata, Bergeria* sp., *Knorria imbricata, Archaeocalamites radiatus, Megaphyton frondosum, Dictyoxylon, Rhynchogonium fayettevillense,* and *Trigonocarpus* sp. It should be emphasized that all of this material previously described has consisted of structureless sandstone casts and molds of the resistant plant parts, and that the more delicate plant parts, particularly foliage, have been conspicuously absent. Recent collecting indicates that the Chester flora of Illinois is considerably more diverse than the previous literature shows. The present paper describes representative examples illustrating the major groups of plants present in the flora and the various modes of preservation encountered.

Stratigraphic Occurrence

The Chester Series in southern Illinois is a sequence of strata, primarily shale, sandstone, and limestone, that reaches a maximum aggregate thickness of approximately 1400 feet (Atherton et al., 1960). The Chester is subdivided into 20 formational units (Fig. 24) according to the most recent classification (Swann, 1963). With the exception of the Grove Church Formation, these units are all named for either their included sandstone or limestone, which often possess distinguishable lithologic characters and outcrop fairly frequently, rather than for their included shale, although this constitutes about half of the series (Potter, 1963). Although plant fossils occur in all three lithologies, the well preserved compressions and petrifactions come largely from shale associated with the sandstone formations. Individual localities are somewhat isolated; however, intensive field work has revealed them to be widespread, both stratigraphically (Fig. 24) and geographically (Fig. 25). Thus far, plant material has come from thirty-three localities in southern Illinois, whose stratigraphic determinations are based on Lamar (1925); Weller and Weller (1939); Weller and Krey (1939); Baxter and Desborough (1965); Amos (1966); Baxter, Desborough and Shaw (1967); and Knight (1968). Terminology follows that presented by Swann (1963) and terminology used in the older reports has been revised in accordance with this.

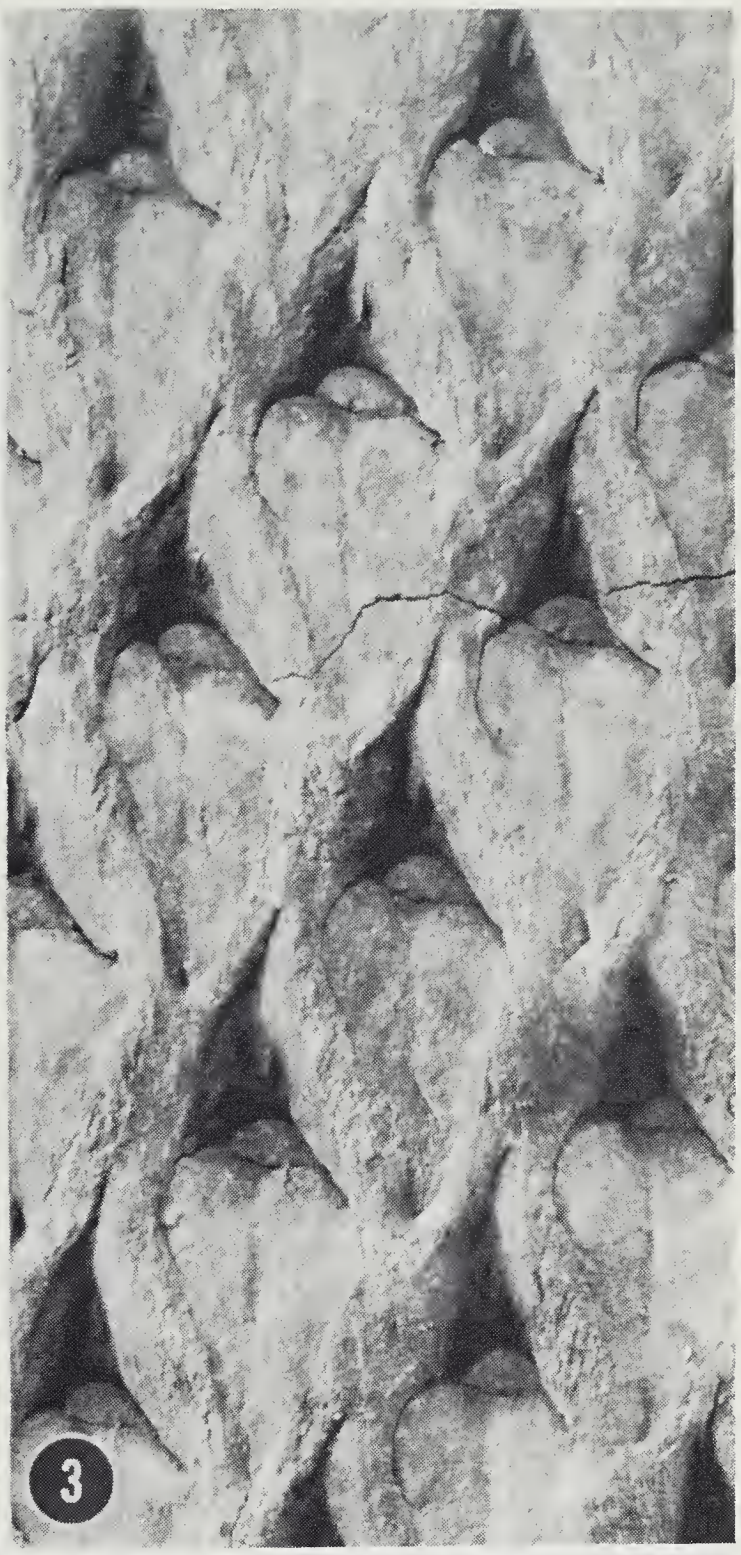
Formations that have yielded fossil plants are indicated by arrows in Fig. 24. Although floras occur from the Bethel Formation near the base, to the Grove Church at the top of the Series, the most important collections have been taken from the Cypress, Hardinsburg, Tar Springs, Waltersburg, Palestine, Degonia, and Grove Church Formations. Of these formations, the Waltersburg is the most important source of petrifactions to date.

Materials and Techniques

Compression specimens illustrated in this paper were photographed dry, since xylene causes most of the plant-bearing shales to disintegrate. The structurally preserved specimens are preserved as pyrite-marcasite petrifactions, occurring either in nodular structures or as isolated axes embedded in the shale. Petrified specimens were embedded in plastic prior to sectioning. After sectioning, the petrified specimens were polished, and etched in nitric acid to increase contrast.

Description and Discussion

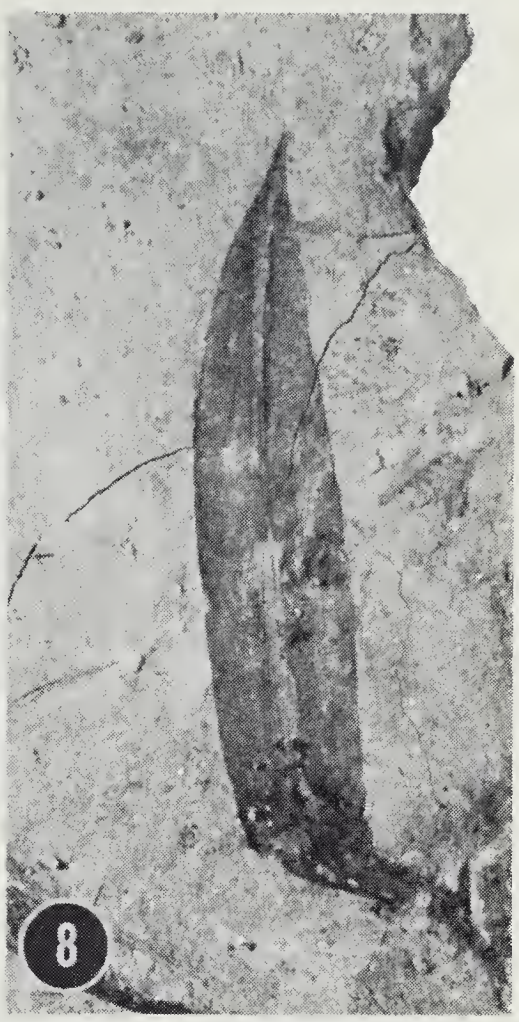
The flora of the Chester Series of Illinois contains a relatively large number of plant forms in comparison with most floras of comparable age from North America. These remains represent several major groups of vascular plants. Arborescent lycopods are well represented by remains of both vegetative and reproductive organs. Impressions of large stems of *Lepidodendron veltheimii* Sternberg (Fig. 3) are most commonly found in sandstone. The figured specimen retains much of the original surface relief and shows the



FIGURES 1, 2. Representative branches of tree sized lycopods with attached leaves. X 1. FIGURE 3. Impression specimen showing characteristic leaf bases of *Lepidodendron veltheimii*. X 2. FIGURE 4. Stem surface pattern of *Lepidodendron volkmannianum* with longitudinally elongate leaf bases in vertical rows. X 2. FIGURE 5. A developmentally old specimen of *Lepidodendron volkmannianum* showing a leaf scar (at arrow) and *Syringodendron*-type subsurface features beneath. X 1.5.

elongate leaf cushions (more than twice as long as they are wide) and the leaf scars which are considerably elevated above the surrounding surface. *Lepidodendron volkmannianum* Sternberg is represented by a large number of branches of various sizes. Figure 4 illustrates a representative specimen showing the characteristic features of the species. Of special interest is a specimen of *L. volkmannianum* shown in Fig. 5 having distantly spaced leaf scars (at arrow) separated by regions of shallow, irregular furrows. The surface pattern of this specimen is interpreted as representing *Lepidodendron volkmannianum* in which the features of the leaf cushion were obscured by the growth of secondary tissue (Lacey & Eggert, 1964). Careful removal of some of the surficial carbon revealed a *Syringodendron* Sternberg subsurface pattern visible in the lower portion of Fig. 5. This apparently represents the first report of a *Lepidodendron* that produced *Syringodendron*-type subsurface features. In contrast to these developmentally old specimens, some of the smaller, presumably more distal branches retain attached leaves (Fig. 1, 2). Reproductive organs of the tree-sized lycopods include cones referred to *Lepidostrobus* Brongniart (Fig. 7) and at least two types of isolated sporophylls. One of these forms of *Lepidostrobophyllum* Hirmer with a lanceolate distal lamina is shown in Fig. 8. *Stigmaria* Brongniart is present both as petrified steles (Fig. 9) and either 3-dimensional casts or flattened impressions in sandstone or shale (Fig. 6, 10, 11). The latter types generally correspond to *S. ficoides* Brongniart (Fig. 6) or *S. stellata* Goeppert (Fig. 11). However, certain specimens that otherwise correspond to *S. ficoides,* occasionally show scars that are surrounded by radiating ridges which are identical to those that characterize *S. stellata* (Fig. 6 and Fig. 10 at arrows). The reticulate pattern that lies between the scars on typical *S. stellata* specimens is either absent or obscure on such casts. The obscurity of this pattern is believed to result from lack of preservation since the typical specimens of *S. stellata* occurring in shale show a well-developed reticulate pattern between the scars while those present in the coarser sandstones do not.

The sphenopsids are represented by *Archaeocalamites* Stur, which was apparently widespread in North America (White, 1937a, 1937b; Bell, 1944, 1960; Arnold and Sadlick, 1962; Lacey and Eggert, 1964; Taylor and Eggert, 1968c) but remains poorly known inasmuch as all of this previously described material consists of structureless casts and impressions. In contrast, specimens of this genus from Chesterian shales in Illinois consist of compressions, petrifactions, or combinations of these two modes of preservation. Stems are found at most shale localities and many of these bear leaves (Fig. 12) which have not previously been demonstrated to be present in material of this genus from rocks of Mississippian age in North America. One to three dichotomies have been observed in the leaves. Cones borne in a whorl are shown attached to *Archaeocalamites* for the first time in North America (Fig. 14). The cone axis lacks any apparent hori-



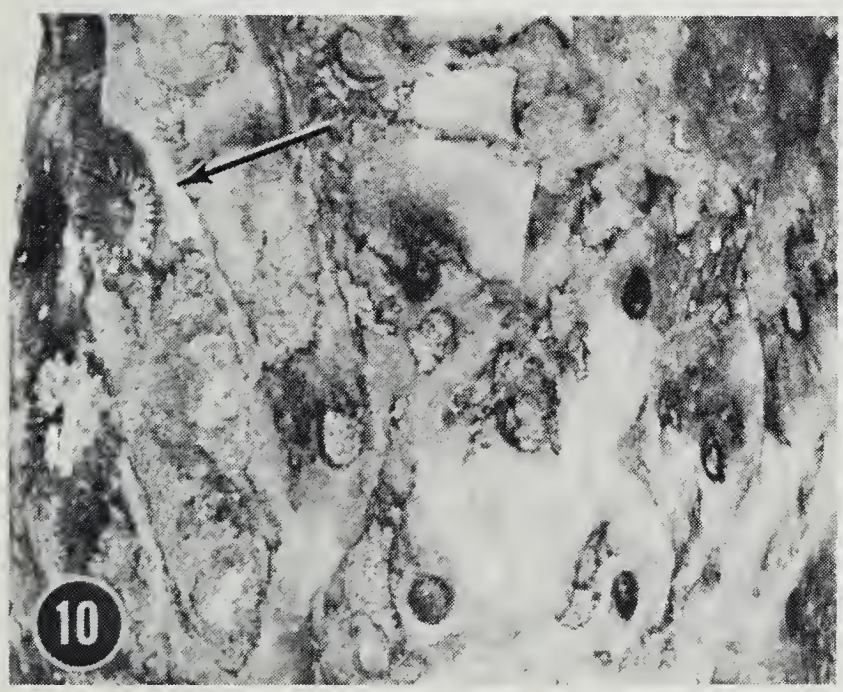


FIGURE 6. Sandstone cast specimen of *Stigmaria ficoides* with a scar of the *Stigmaria stellata* type (at arrow). X 0.5. FIGURE 7. A representative *Lepidostrobus*. X 1. FIGURE 8. Isolated sporophyll, *Lepidostrobophyllum*, with a lanceolate distal lamina. X 2. FIGURE 9. Petrified stele of stigmarian axis. X 2. FIGURE 10. Portion of stigmarian cast in Figure 6 showing detail of scars. X 1. FIGURE 11. Typical *Stigmaria stellata* illustrating surface pattern. X 1.

zontal segmentation indicative of nodes; instead, uninterrupted longitudinal ribs are present. Numerous petrified stems have been collected, one of which is illustrated in Fig. 13 showing its external features. Figure 15 shows a cross section of a similar stem that had eight protoxylem areas in the complete section, each of which was apparently developing a canal at the time of death. Even small branches, such as the one illustrated, possess a conspicuous zone of secondary xylem.

Pterophyte and cycadophyte remains constitute a diverse assemblage in the Chester of southern Illinois. Representative of the coenopterid ferns is the genus *Botryopteris,* remains of which have been found in pyritic nodules from the Waltersburg Formation. Foliar compressions representing pinnules of *Fryopsis* Wolfe (=*Cardiopteris* Schimper) (Fig. 17) are well represented in the flora. Isolated pinnules range from orbicular to ovate, with an acute to cordate base, and were borne on a slender stalk, part of which is visible in Fig. 17. Figure 19 shows several smaller, more elongate pinnules attached alternately along a slender rachis. Foliage of this type probably represents distal portions of *Fryopsis* fronds. Highly dissected foliage of the type placed in the genus *Rhodea* Presl is almost always present at shale localities (Fig. 16). Certain of the ultimate divisions are much broader than others on some of the specimens such as that figured. Although the reason for this variability is not clear, it must be considered in evaluating fragmentary specimens of *Rhodea.* Such specimens have been used as the basis for instituting several species of this genus from Mississippian age rocks of North America. Although somewhat less widely distributed, several types of *Sphenopteris* (Brongniart) Sternberg are present, forming an important element of the flora. The figured specimen (Fig. 21) is a common type that appears to conform to *S. mississippiana* White, although the very fragmentary nature of the type material (White, 1937a) renders the determination uncertain. Less commonly encountered is foliage of a type generally referred to as *Adiantites* Goeppert (Fig. 23) in which the pinnules are alternate, but highly variable in form. The number of primary lobes of the pinnules varies from two to eight and these lobes may be further subdivided distally. Striations paralleling the margins of the pinnules evidently reflect the venation pattern. A variety of other foliage types is present and includes specimens that are comparable to ones that have been described under the generic name *Sphenopteridium* Schimper (Fig. 22). Fructifications of the extinct cycadophyte group Pteridospermales also occur. A synangiate pollen organ of the type that is generally referred to the genus *Telangium* Benson is displayed in Fig. 17. Its parent plant is presently unknown; however, the branching pattern is similar to that found in *Rhodea.* Seed compressions are present at nearly all plant-bearing horizons. These include the specimen shown in Fig. 20 which is best assigned to the seed cast genus *Rhynchogonium* Heer, specimens belonging to *Trigonocarpus* Brongniart, and others which have not yet

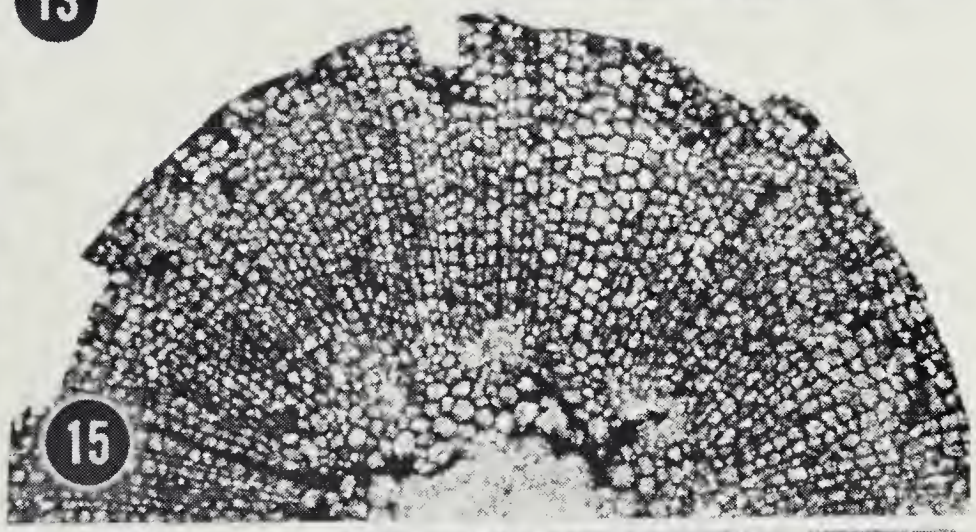
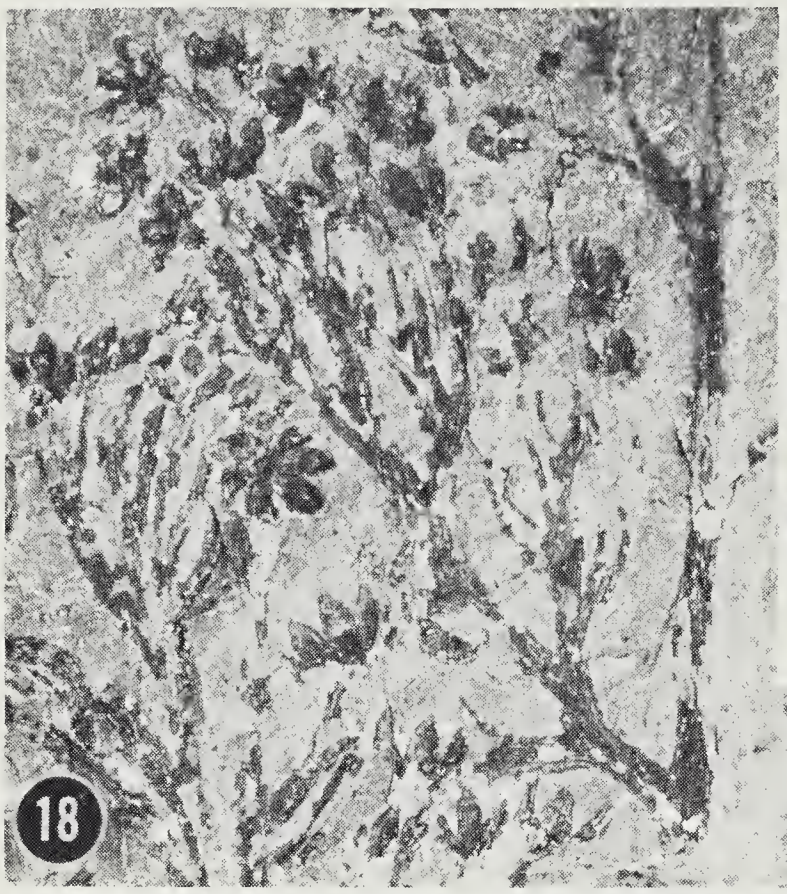
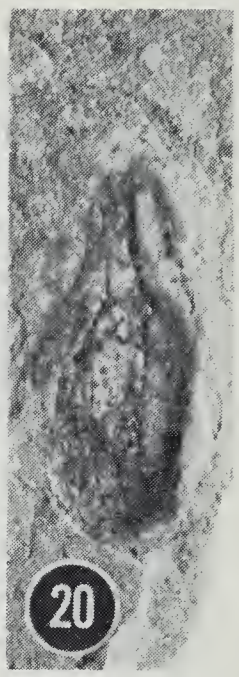


FIGURE 12. *Archaeocalamites*. Small branch combining pyrite petrifaction of the stem with compression of the attached leaves. X 1. FIGURE 13. External view of a petrified branch of *Archaeocalamites*. X 1. FIGURE 14. *Archaeocalamites* bearing a whorl of attached cones. X 1. FIGURE 15. Cross section of petrified stem of *Archaeocalamites*. X 55. FIGURE 16. A representative compression specimen of the genus *Rhodea*. X 1. FIGURE 17. Isolated pinnule of *Fryopsis*. X 2.





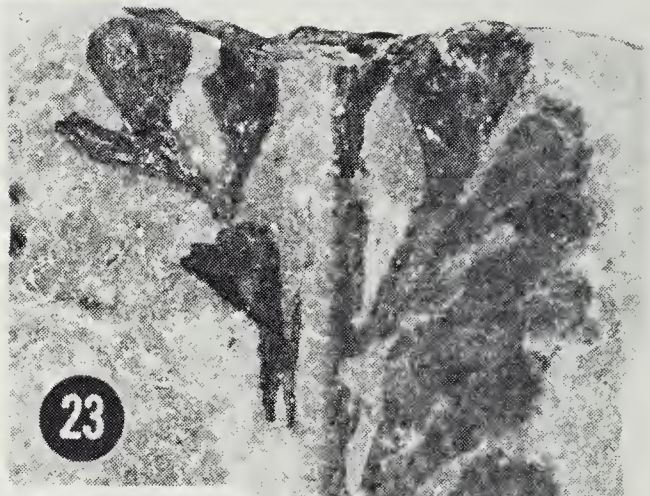


FIGURE 18. Synangiate pollen organ of the type usually referred to *Telangium*. X 5. FIGURE 19. Attached pinnules probably representing the distal portion of a *Fryopsis* frond. X 2. FIGURE 20. Seed referable to the genus *Rhynchogonium*. X 1. FIGURE 21. *Sphenopteris* resembling *S. mississippiana*. X 5. FIGURE 22. *Sphenopteridium*-like foliage. X 2. FIGURE 23. *Adiantites* showing characteristic lobed pinnules. X 2.

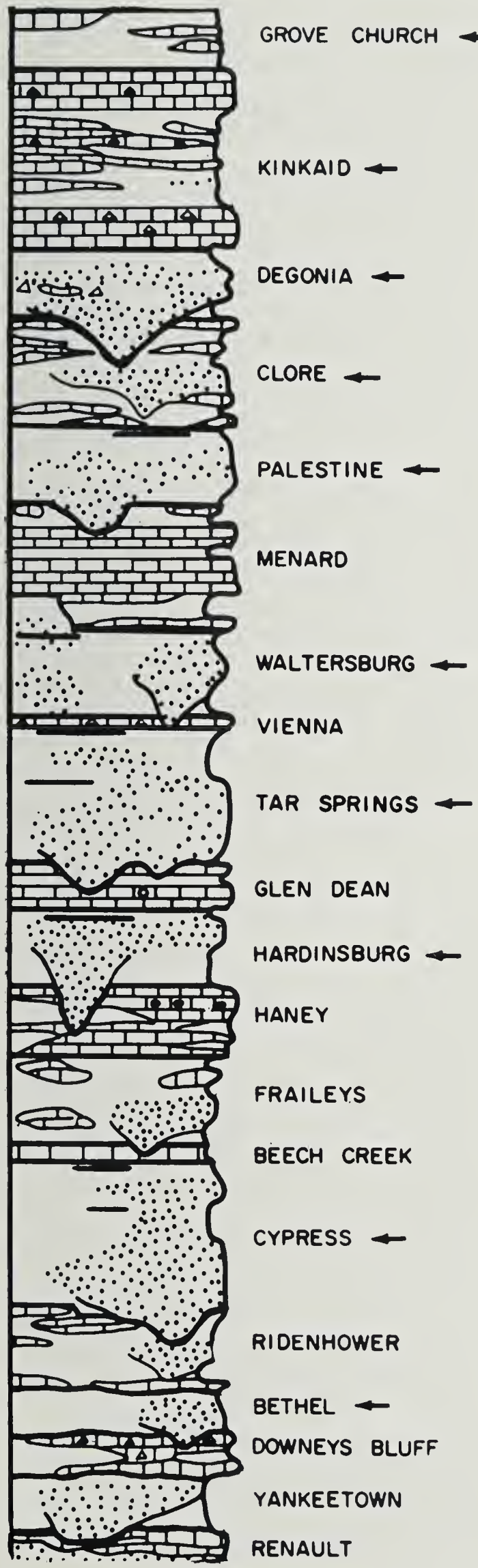


FIGURE 24. Generalized stratigraphic column of the Chester Series of Illinois. Formations from which fossil plants have been collected are indicated by arrows. Standard symbols are used to indicate the various lithologies with the exception of shale which is indicated by areas of solid white. (Modified from Swann, 1963).

been assigned to specific genera.

The Chester Series flora of southern Illinois is outstanding among floras of a comparable age from North America for several reasons. The different modes of preservation should make possible the determination of a variety of types of information including external features, internal anatomy, the nature of pollen and spores, and features of the cuticle. This diversity of preservation is especially noteworthy because of the relatively large number of taxa present in the flora. Unlike most Late Mississippian floras from North America, the southern Illinois flora contains numerous types of foliage. A much better comparison will, therefore, be possible between the Illinois flora and many of the European Lower Carboniferous floras in which similar foliage constitutes the

FIGURE 25. Outline map of the southern portion of Illinois. The outcrop area of the Chester Series is indicated by stippling. Large dots represent fossil plant localities.

major part of the flora. A knowledge of the plants present in the type region of the Chester Series will be of obvious usefulness for comparison with the floras of other Chesterian age rocks from North America, and may provide valuable information for determining the stratigraphic position that the Chester Series occupies in relation to the major divisions of the European Carboniferous.

Acknowledgments

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EXPERIMENTALLY INDUCED VARIATION AND THE ENVIRONMENTAL SIGNIFICANCE OF CORRENSITE

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ABSTRACT. — Clay minerals of the corrensite type present some particular problems in the identification of the interstratified components. Choice of a reflection or combination or reflections from which unit basal spacings are calculated, choice of method of heat application, and history of the specimen before analysis may each induce large variations in the X-ray properties of corrensite.

The ubiquitous association of sedimentary corrensite with saline environmental indicators and the absence of corrensite in the sediment loads of modern streams implies that sedimentary corrensite is always a diagenetic product of saline conditions.

The first descriptions of a corrensite-like clay mineral were made by Stephen and MacEwan (1951) and Honeyborne (1951), both from the Keuper Marl of Great Britain. The term *corrensite* was first used by Lippman (1954) to describe a similar interstratified clay mineral from the Keuper Sandstone of Germany and later extended to a fourth occurrence from the Buntsandstein (Lippmann, 1956). In the following several years new occurrences multiplied (Earley, Brindley, McVeagh, and Vanden Heuvel, 1956; Bradley and Weaver, 1956; Martin Vivaldi and MacEwan, 1957; Sudo, 1959; Grim, Droste, and Bradley, 1960; Braitsch, 1960; Peterson, 1961, 1962; Millot, Lucas, and Wey, 1963). The term *corrensite* is now well entrenched in the literature of general geology and new discoveries of its occurrence no longer constitute major finds.

It has long been known that the described corrensite specimens do not behave identically under experimental treatment. These variations were ascribed to differences in layer composition, and it was proposed that *corrensite* actually is a group of minerals composed of the several possible combinations of chlorite, swelling chlorite, vermiculite, and smectites. Because of this interpretation Martin Vivaldi and MacEwan (1960), Frank-Kamenetsky (1960) and MacEwan, Ruiz Amil, and Brown (1961) urged that the term *corrensite* be restricted to Lippmann's original and "type" corrensite and that the remainder of these combinations receive new names. Unfortunately, the identity of the layer components in the original material has never been satisfactorily determined. Furthermore, Lippman's second occurrence certainly differed from his first, and, although the first ought to have priority, it is common to see the term *corrensite* used for the second variety even among those who advocate restricted usage of the term. Herein the term *corrensite* is used in its broadest sense, i.e., to include those clay minerals consisting of the regu-

lar interstratification of an expansible combination of 14 angstrom clay minerals.

In spite of awareness of the inherent variability of corrensite, identification of the component layers has proven to be difficult. An experimental scheme to distinguish among the possible layer constituents was first proposed by Martin Vivaldi and MacEwan (1906), and has gained general use among geologists who do not wish to go into detailed structural analyses. However, difficulties have often arisen with such schemes when replicate analyses are made on single specimens. Such variation can be attributed only to variations in experimental procedure. Recent studies on a series of corrensite specimens from the Sespe Formation of California are used here to illustrate these experimentally induced variation.

Sample Material

Specimens containing corrensite were collected from four outcrop localities of the Sespe Formation, a mid-Tertiary non-marine redbed unit which outcrops in southern California in the general vicinity of Los Angeles. The four localities are Old San Marcos Pass northwest of the city of Santa Barbara, Sycamore Canyon north of Santa Barbara, Casita Pass northwest of Ventura, and Agua Dulce Canyon 3 miles northeast of Lang (Flemal, 1966). At each locality the corrensite occurs only in gypsiferous strata or in strata associated with gypsum-bearing beds, and is generally associated with minor amounts of chlorite and illite. Smectite is the dominant clay mineral in the large portion of the Sespe Formation that does not contain corrensite, but it was not identified as a separate species in any of the corrensite-bearing strata.

Sample Preparation

Preparation of the samples for X-ray analysis was achieved in the following steps:

1) 0.5 to 2.0 grams of material were lightly ground in a mortar and sieved to less than 0.88 mm in diameter. Six ml of distilled water and 4 drops of concentrated sodium hexametaphosphate were added to the powder.

2) The samples were agitated in an ultrasonic vibrator for one hour to effect disaggregation. Each sample was then mixed and allowed to settle for 3½ hours, after which the liquid portion was decanted and placed on round cover slips to air-dry.

3) Four X-ray slides were made from each decant. A single slide was used for both untreated X-ray and glycolated X-ray runs. A second slide from the same decant was used for heat experiments. The two remaining slides were used to check results obtained from the first two.

4) For glycolation, each slide was placed in a covered box containing an open well of ethylene glycol. Complete glycolation was usually achieved at room temperature within one week. For some slides, the box was held in an oven heated at 35 degrees C. This procedure usually affected glycolation within 24 hours, but tended to cause minor warping of the thin clay film.

5) Heat treatment experiments,

TABLE 1.—Basal reflection properties of four untreated samples of corrensite from a single microscopically uniform hand specimen. Measurements in angstroms.

Reflection	Intensity	Samples (1)	(2)	(3)	(4)	Average	Calculated Unit Basal Spacing	Deviation from Average	Deviation from Calc. 002
001	s	28.5	28.5	28.5	28.5	28.5	28.5	+0.9	+1.2
002	vs	13.7	13.7	13.6	13.6	13.65	27.30	—0.3	0.
003	s	9.0	8.93	8.93	8.93	8.94	26.82	—0.74	—0.48
004+chlorite?	m	7.15	7.13	7.13	7.13	7.14	28.56	+1.00	+1.26
005?	mb	5.34	5.37	5.30	5.29	5.33	26.65	—0.91	—0.65
006	w	4.77	4.77	4.74	4.77	4.76	28.56	+1.00	+1.26
007	vw	**	3.78	3.78	3.78	3.78	26.46	—1.10	—0.84
008+chlorite?	w	3.565	3.55	3.55	3.54	3.55	28.40	+0.84	+0.90
009	w	2.97	2.97	2.96	2.95	2.96	26.64	—0.92	—0.66
							27.56 Average		

** = reflecion absent.

which provided highly variable results, were conducted in a variety of manners, as discussed later.

6) All X-ray runs employed a rotating sample holder spinning at 77-1/7 rpm. This device gave the most reproducible machine results. Increased resolution of the peak positions was achieved by scanning at ½ degree 2-theta per minute.

Experimental Results

Corrensite is identified on the basis of a somewhat irregular but orderly series of basal reflections in untreated, glycolated, and heated samples. In some samples of the Sespe corrensite it is possible to distinguish reflections up to the thirteenth order, although more commonly ninth order reflections constitute the maximum. The first through third order reflections are characteristically the strongest. The higher order reflections display a systematic alternating deviation from the average calculated unit basal spacing in both untreated (table 1) and glycolated (table 2) samples. This phenomenon was also noted by Grim, Droste, and Bradley (1960, p. 229-232), and is attributed to the occasional juxtaposition of layers of like composition in the otherwise alternating interstratification. In general the (001) reflection tends to indicate a larger unit basal spacing than do the higher order reflections, particularly in the glycolated samples (table 2). However, this is in part, at least, a function of the difficulty of making precise angstrom conversions at these low angles of reflection. In these cases choice must be made as to which measurement best reflects the unit basal spacing.

For the Sespe corrensite, the average unit basal spacing of 28.5 angstroms for the untreated samples (table 1) and the average unit basal spacing of 31.2 angstroms for the glycolated samples (table 2) suggests the interstratification of a 14-14 ang-

Table 2.—Basal reflection properties of four glycolated samples of corrensite from a single microscopically uniform handspecimen. Measurements in angstroms.

Reflection	Intensity	Samples (1)	(2)	(3)	(4)	Avg.	Calculated Unit Basal Spacing
001	s	32.7	34.0	32.7	32.7	33.0	33.0
002	vs	15.5	15.6	15.6	15.5	15.55	31.00
003+illite	m	10.2	10.0	10.1	9.98	10.1	30.3
004	s	7.82	7.82	7.82	7.79	7.81	31.24
006+illite	m	5.15	5.18	**	5.18	5.17	31.02
007	w	4.47	4.48	**	**	4.48	31.36
008	vw	**	3.86	**	**	3.86	30.88
009	m	3.46	3.47	3.46	3.46	3.46	31.14
0011	w	2.84	2.84	**	2.84	2.84	31.24
							31.2 Average

strom pair, one of which is expansible to 17 angstroms. However, if only the measured (001) values are used, the glycolated samples at an average of 33 angstroms suggest that both members of the pair are expansible to nearly 17 angstroms. If the latter may be attributed to measurement error, according to the Martin Vivaldi and MacEwan scheme, the 14-14 pair would be normal chlorite with either smectite or swelling chlorite. Attempted distinction between the swelling chlorite and smectite would normally be made by heat treatment (Martin Vivaldi and MacEwan, 1960, p. 178). However, in the case of the Sespe corrensite, for which differing methods of heat treatment were applied, the results are not diagnostic.

Four methods of heat treatment were applied to the Sespe corrensite. The first two consisted simply of placing a prepared slide directly on a hot plate for one hour. The hot plate was either cold and allowed to heat gradually to 450 degrees C. (method #1), or already heated to and held at 450 degrees C. (method #2). Conflicting results were obtained: in method #1 the resultant trace showed an irregular series of reflections, the largest of which was at 13.7 angstrom; the method #2 trace showed no peaks at all, indicating that the interlayered water was expelled from the corrensite structure so fast that the disruption destroyed any regularity of layering.

The second two heating methods were developed to allow sequential X-raying in such a manner as to permit tracing the changes induced by the heating. Method #3 consisted of placing a sample in a closed crucible which was held at approximately 450 degrees C. during the experiment. At intervals beginning at 1.5 minutes the specimen was removed from the crucible and X-rayed over the range of the first four basal reflections. The results (figure 1 and table 3) show a gradual decrease in intensity and spacing of the peaks, particularly the (001) and (003) reflections which decreased in spacing 0.9 and 1.00 angstroms respectively before they were lost. A similar decrease but of lesser magnitude occurred in the (002) reflection which fell from 13.6 to 13.2 angstroms after 45 hours of heating.

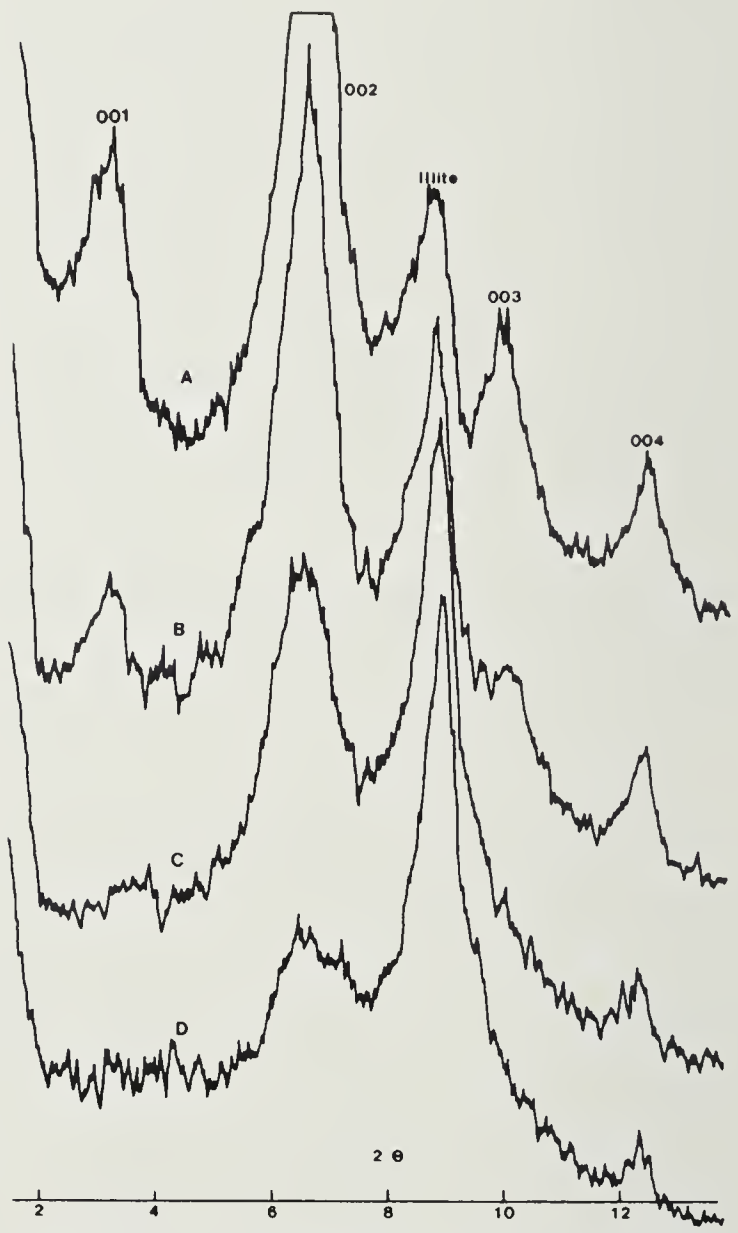

FIGURE 1. Sample x-ray diffraction traces of corrensite-illite clay mixture. Heat treatment method #3 (see text). A. Unheated. B. 9.5 minutes. C. 2.0 hours. D. 45.0 hours.

TABLE 3.—Results of sequential heating experiment on *corrensite*, method #3 as described in text. Intensity (I) measured as peak height above an arbitrary baseline.

Temperature	Time	001		002		Illite		003		004	
		Å	I	Å	I	Å	I	Å	I	Å	I
25 C	0	29.4	3.9	13.6	8.9	10.2	3.5	8.93	2.5	7.13	1.2
450 C	1.5m	28.5	3.4	13.6	7.4	10.2	4.0	8.88	2.0	7.16	1.4
450 C	4.5m	28.0	2.7	13.7	6.9	10.2	4.4	8.84	1.8	7.13	0.8
450 C	9.5m	28.5	2.2	13.7	6.9	10.1	4.5	8.84	1.7	7.13	0.8
450 C	24.5m	28.5	2.0	13.8	6.7	10.2	4.8	8.84	1.5	7.16	0.8
450 C	54.5m	28.5	1.7	13.8	5.3	10.1	5.3	.....	1.5	7.19	0.5
450 C	2.0h	.....	.....	13.7	4.2	10.1	5.5	.....	.....	7.22	0.5
450 C	8.0h	28.5?	1.6	13.8	4.6	10.1	5.8	.....	.....	7.19	0.6
450 C	20.5h	.....	.....	13.3	2.8	10.0	6.1	8.67	1.1	7.13	0.5
450 C	25.0h	.....	.....	13.2	2.6	10.1	6.0	8.34	0.7	7.16	0.5
450 C	30.5h	.....	.....	13.2	2.5	10.0	5.2	7.96?	.....	7.13	0.4
450 C	45.0h	.....	.....	13.2	2.1	10.0	5.4	.....	.....	7.16	0.4

Method #4 consisted of placing a slide prepared identically to the one used in method #3 in an oven which was allowed to heat up gradually from room temperature to 180 degrees C. The results are presented in figure 2 and table 4. There are several significant differences between these results and those produced by method #3. In general the peaks showed the same decrease in intensity, with the (001) reflection disappearing after 27.5 hours of heating. The (003) reflection, which was undetectable during the latter part of the method #3 treatment, first showed a decrease in intensity accompanied by broadening of the peak, and then an increase in intensity and sharpening of the reflection. Even more intriguing is the greater collapse of the unit basal spacing which fell to 24.8 angstroms (2 X 12.4), versus to 26.4 angstroms (2 X 13.2) for method #3.

Few of these peculiarities produced by differing heat treatments have been discussed in the literature. The gradual loss of the (001) reflection in heating experiments, is not unusual, as is shown by Lippmann's (1956), Earley, Brindley, McVeagh and Vanden Heuval's (1956), and Sudo's (1959) data. Smith (1960, p. 285) suggests that his loss is due to undefined "structural irregularities," but the phenomenon still remains largely unexplained. One method by which this loss might be achieved is by having the heat produce an homogenizing effect on the individual layers of the corrensite. This could be done by driving out water layers that occur between every second layer of otherwise similar inter-layered components. Such a phenomenon would occur if the interlayered components were swelling chlorite and normal chlorite. This explanation, however, is not entirely adequate since the higher order odd reflections persist, even though the (001) reflection disappears.

The type of variable intensity shown by the (003) reflection in method #4 is explained by uneven loss of water from the structure, which caused a temporary disordering of the reflection. But why this should be more pronounced in one method than in the other is unexplained. Also, why the two methods produced different basal spacings is undetermined. If either of these two phenomena were due to the degree of dehydration alone, the results of the last two heat methods would likely have been reversed, since the third method involved greater temperature than did the fourth.

If only the results of the first or third heating methods were available, the conclusion would be that the Sespe corrensite consists of two species which have 13-14 angstrom spacings when collapsed (i.e., normal chlorite and expandable chlorite). On the other hand, if only the results of method #4 were available, the suggestion would be that a 14-10 angstrom collapsed pair was present (normal chlorite and smectite). Clearly, the choice will depend on the treatment procedures.

The behavior of the 10.1 angstrom reflection in the heated samples (figures 1 and 2) does give some suggestion for a 14-10 angstrom collapsed pair, in as much as the increase in its intensity may be more than can be expected for simple or-

TABLE 4.—Results of sequential heating experiment on *corrensite*, method #4 as described in text. Intensity (I) measured as peak height above an arbitrary baseline.

Temperature	Time	001		002		Illite		003		004	
		Å	I	Å	I	Å	I	Å	I	Å	I
25 C	0	29.4	3.9	13.6	8.9	10.2	3.5	8.93	2.5	7.13	1.2
100 C	20.0m	29.9	3.7	13.6	8.1	10.2	3.6	8.93	2.5	7.13	1.6
150 C	2.0h	28.5	2.5	13.6	5.9	10.2	4.3	8.75	1.8	7.19	1.8
180 C	8.0h	26.8	1.4	13.6	6.3	10.2	4.6	8.75	1.6	7.19	1.1
180 C	18.0h	.....	1.5	12.8	4.8	10.1	5.5	8.11	1.9	7.19	1.1
180 C	23.0h	26.0?	1.8	12.6	3.8	10.1	5.2	8.14	1.8	7.13	1.0
180 C	27.5h	.....	.....	12.6	3.7	10.1	4.9	8.18	1.7	7.13	0.8
180 C	43.0h	.....	.....	12.4	3.4	10.1	4.5	8.18	1.5	7.19	0.7

dering of an illite (001) reflection. However, this is not conclusive proof.

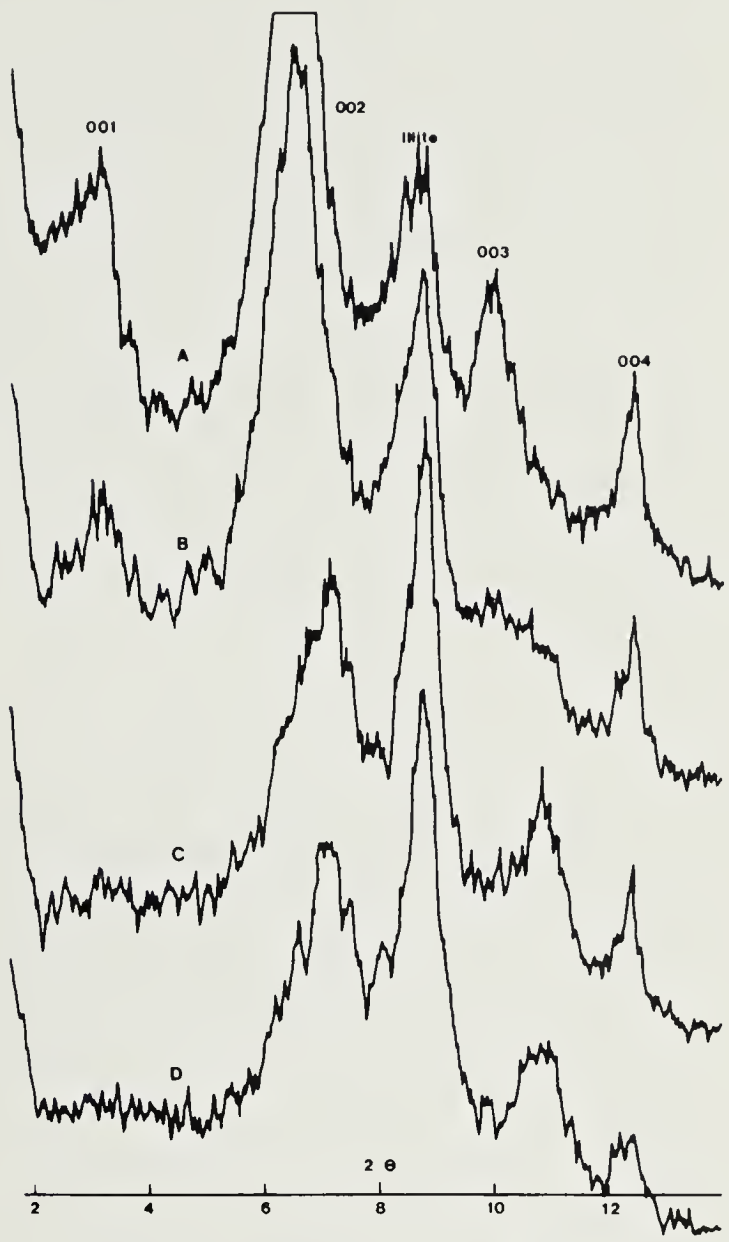

FIGURE 2. Sample x-ray diffraction traces of corrensite-illite clay mixture. Heat treatment method #4 (see text). A. 20.0 minutes. B. 8.0 hours. C. 23.0 hours. D. 43.0 hours.

Prolonged drying of a specimen before analysis also introduces a complicating factor. The original experiments on the Sespe corrensite were run in 1966. The specimens were at that time fresh from the field where they had been collected at some distance back from the outcrop face. In 1968 one of the same specimens used earlier was again analyzed in exact repetition of the earlier procedures. The results were similar

with the exception that all of the corrensite reflections were remarkably reduced in intensity, similar to those of a heated specimen. In the intervening two years the specimen had been stored at normal room temperatures without humidity control. The corrensite had dehydrated, apparently irreversibly, since soaking of corrensite in water for one month did not restore the original condition. Caution is therefore called for in dealing with corrensite samples which may have been altered in nature at the outcrop before being collected, or while sitting in a laboratory.

Summary

It remains difficult to identify the component species in the mineral corrensite by any simple identification scheme. It is natural to expect that a mineral such as corrensite which has a high potentiality for chemical and structural variation does indeed exhibit these variations in nature. However, many of the observable properties of this mineral may in fact be the result of experimental rather than natural variations. Of particular importance is the duration and temperature of heating, and the conditions to which the sample was exposed before analysis.

Environmental Implications Of Sedimentary Corrensite

Minerals of the corrensite type have been identified in two environments: sedimentary and replacement, the latter probably hydrothermal. Table 5 lists the published occurrences of corrensite in relatively undisturbed sedimentary rocks. Significantly, in each case the corrensite is associated with strata of known or suspected saline depositional environments. Furthermore Peterson (1962, p. 18) observed that corrensite is never found in sediment loads of modern streams. The observation made here that the corrensite structure is destroyed through long periods of exposure to air probably accounts for this observation. Accordingly, sedimentary corrensite is probably always diagenetic.

The ubiquitous association of corrensite with salines implies that either the salines themselves or the saline environment is necessary for the corrensite to develop. This suggests further that corrensite is an indicator of a warm dry climate, at least to the degree that a saline environment is indicative of these conditions.

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TABLE 5.—Known occurrences and association of sedimentary *correnSite*.

Strata	Location	Age	Association	Reference
1) Keuper Marl	England	Trias	Red beds	Stephen and MacEwan, 1951; Honeybourne, 1951
2) Keuper	Germany	Trias	Gypsum, red beds, dolomite, evaporites	Lippmann, 1954; Echle, 1961
3) Buntsandstein	Germany	Trias	Gypsum, rock salt, red beds	Lippmann, 1956
4) Yates Formation	West Texas	Permian	Dolomite, evaporites	Earley *et al*, 1956
5) Brazer Lm.	Colorado	Miss.	Limestone	Bradley and Weaver, 1956
6) Keuper	France, Spain	Trias	Gypsum, anhydite, limestone, dolomite, red beds	Martin Vivaldi and MacEwan, 1957
7) Salodo Formation	New Mexico	Permian	Potash Beds	Grim, Droste, and Bradley, 1960
8) Strafurtsalz	Germany	Permian	Evaporites	Braitsch, 1960
9) Chesterian	Tennessee	Miss.	Limestone, dolomite, evaporites, red beds	Peterson, 1961; 1962
10) Jura Basin	France	Trias	Gypsum, limestone, salt	Millot *et al*, 1963
11) Sespe Formation	California	Oligo.	Red beds, gypsum, borates, limestone.	This report

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REGIONAL DIFFERENCES IN WEIGHT AND ANTLER MEASUREMENTS OF ILLINOIS DEER

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ABSTRACT. — Northern Illinois deer had a significantly greater dressed weight and antler beam diameters than southern Illinois deer. The incidence of spike-horned males was 7 percent for the north and 16 percent for the south. The role of land-use, habitat quality and soils are discussed in relation to deer nutrition as possible explanation of these differences in northern and southern deer.

Various experimental studies with the white-tailed deer, *Odocoileus virginianus,* have established a relationship between nutrition, body size and antler development (Nichol 1938; Davenport 1939; French et al. 1956). These studies demonstrate that controlled variation in diet produces a difference in weight and degree of antler development. Evidence that such a phenomenon exists under natural conditions has been recorded by Severinghaus et al. (1950), Severinghaus (1955), Gill (1956), Adams (1960), Banasiak (1961) and others. Generally they have shown regional differences in deer size and antler development as being related to range quality. The objectives of my study were to use age-weight-antler beam diameter criteria as indicators of regional nutritional level in Illinois white-tailed deer, and to survey regional land-use practices and soil qualities as inferences to habitat quality and nutrition of Illinois deer.

METHODS

Two segments of Illinois were studied. A northern area consisted of JoDaviess and Carroll counties (Fig. 1). Jackson, Jefferson, Johnson, Gallatin, Union and Williamson counties comprised the southern area. Data utilized were obtained from county check stations during the 1966 and 1967 Illinois state deer-hunting season. All deer were

FIGURE. 1. Study areas and counties of Illinois represented in the study.

weighed (field dressed), aged (Severinghaus (1949), and the diameter of the left antler beam measured to the nearest millimeter, 1 inch above the pedicel.

The t-test for independent samples was used for all comparisons involving two means (north-south). An asterisk (*) indicates statistical significance in all tables; $P \leq .05$ was selected for all statistical tests.

Results

Comparison of Illinois Deer Weights

Analysis of weight data showed a significant difference in dressed weight between northern and southern Illinois deer of all age classes except males 4½-years old and older; northern deer were heavier in all instances (Tables 1 and 2). The significant mean weight differences of northern and southern Illinois deer suggest a nutritional (habitat quality) difference in these two areas of the state.

Comparison of Illinois Deer Antler Development

Mean antler beam diameters of each age-class were significantly greater in northern deer than in southern deer (Table 3). These dif-

Table 1.—Comparison of field-dressed weights of male deer, by age-classes, for northern and southern Illinois.

Age	Mean Weight (lbs.)		Range		$S\bar{d}$	N		t
	North	South	North	South		North	South	
½	74	61	39–100	33–107	0.77	272	421	17.2*
1½	128	112	85–190	72–150	1.26	193	402	12.5*
2½	160	135	105–211	81–219	3.31	83	178	7.5*
3½	173	149	131–220	88–220	4.83	40	127	4.9*
4½+	164	164	141–186	91–203	8.48	10	63	0.05

Table 2.—Comparison of field-dressed weights of female deer, by age-classes, for northern and southern Illinois.

Age	Mean Weight (lbs.)		Range		$S\bar{d}$	N		t
	North	South	North	South		North	South	
½	66	53	39–93	23–87	0.87	221	305	15.2*
1½	100	85	74–134	59–114	0.41	121	192	38.2*
2½	111	93	86–144	62–131	1.56	93	137	11.3*
3½	113	93	91–145	73–127	2.55	29	95	7.9*
4½+	114	95	90–133	74–126	2.97	19	66	6.5*

TABLE 3.—Comparison of antler beam diameters, by age-classes, for northern and southern Illinois deer.

Age	Mean Antler Beam Diameter (mm)		Range		$S\bar{d}$	N		t
	North	South	North	South		North	South	
1½	23.8	21.6	14–32	10–32	0.32	150	391	6.8*
2½	31.2	27.1	20–45	11–43	0.79	63	175	5.1*
3½	37.6	31.5	25–48	18–47	1.75	30	124	3.5*
4½+	40.8	35.7	35–48	15–51	2.54	7	62	2.0*

ferences also suggest a nutritional (habitat quality) difference in the two study areas.

A third measure of habitat quality was the frequency of occurrence of spike-horned 1½-year old male deer. Severinghaus (1950) indicated that 80 percent of the 1½-year old deer from the poor quality Adirondack region developed only spike horns. Banasiak (1961) reported that 63 percent of yearling bucks in Maine had spike horns. Adams (1960) found a spike horn incidence of 98 percent in 1957 for over-populated northeastern Alabama habitat. Of 150 yearling males checked in northern Illinois, 7 percent showed spikes while in southern Illinois 16 percent of 402 yearlings were so recorded. The data are consistent with trends suggested by weight and antler beam findings, and present another indication of regional differences in Illinois deer and implied habitat quality.

Comparison of Land-Use Practices

Obvious differences are evident with regard to the extent of forested land and the type of agriculture practices for the two study areas; however, the extent of agricultural activity is comparable in both areas (Table 4). Forested land comprises 10 percent of the northern study area compared to 30 percent in the southern study counties. Total agricultural area (currently in production) is slightly greater in the northern area (39.8 percent) than in the southern area (32.1 percent). Differences were found in the type and extent of cropping activity in the two study areas. In the north the order of cropland significance was corn 55.1 percent, hay crops 26.8 percent (92 percent alfalfa and alfalfa mixtures, 8 percent clover-timothy and other grasses), oats 13.5 percent, soybeans 2.1 percent and wheat 0.1 percent. In the south the order of cropland significance was corn 43 percent, soybeans 29.5 percent, wheat 16 percent, hay crops 10.9 percent (23 percent alfalfa and alfalfa mixtures, 77 percent clover-timothy and other grasses) and oats 0.3 percent.

Soil Comparisons

To permit a comparison of soils found in the northern and southern study areas a numerical rating system has been devised. Such a sys-

TABLE 4.—Comparison of land-use practices for northern and southern Illinois study counties.

County	All Land[1]	Forest	Agriculture[3]	Agricultural Land[2] (Expressed as % of all Agriculture Land)				
	Acreage (Thousand)	% All Land	% All Land	Corn	Soybean	Wheat	Oats	Pasture
North								
Carroll	299.5	7.0	54.3	65.6	2.9	.2	12.1	18.9
JoDaviess	393.0	15.1	38.9	47.0	1.0	.....	15.0	36.5
Total	792.5	10.1	39.8	55.1	2.1	0.1	13.5	26.8
South								
Gallatin	209.9	26.1	54.5	72.6	14.2	10.2	0.1	2.6
Jackson	385.9	35.0	34.5	37.8	28.5	23.3	0.5	8.8
Jefferson	367.4	17.8	45.9	28.9	44.7	17.8	0.2	8.0
Johnson	220.8	38.0	16.0	43.6	16.7	3.5	0.2	35.0
Union	265.0	36.6	23.5	41.1	20.9	17.4	0.2	19.5
Williamson	273.4	30.3	14.9	37.1	37.1	8.8	0.1	15.9
Total	1,732.4	30.0	32.1	43.0	29.5	16.0	0.3	10.9

[1] Data from Essex and Gansner (1965).
[2] Data from Illinois Agricultural Statistics, Annual Summary-1968.
[3] Includes only agricultural land in production during 1966.

tem facilitates comparisons of soil characteristics by quantifying descriptions such as "rapid", "slow", "moderate", etc. The rating system shows differences in general soil qualities, generally resulting in higher ratings for soil associations of northern study counties (Table 5). Since the extent of each soil association differs, a weighted average was computed for upland, terrace, and bottomland soil associations of the two study areas. Upland, terrace and bottomland ratings for the northern counties were 20.3, 16.1 and 21.2 respectively, compared to ratings of 16.3, 17.1 and 17.9 for southern study counties. No statistical evaluation is applicable to these values.

Discussion

Land-Use Practices

Essex and Gansner (1965) define forest land to be at least 10 percent stocked by forest trees of any size, or formerly having such tree cover, and not currently developed for nonforest use. On this basis, forested lands in the southern Illinois region are three times that of the northern area (Table 4). Hence there is more forested habitat available for southern Illinois deer and presumably a greater capacity to carry deer populations. It is unlikely that all forest land constitutes suitable deer habitat as quality is an important consideration when comparing woodland habitat. Because investigations on available browse species of Illinois forest vegetation and their nutritional quality are lacking no attempt has been made to evaluate this aspect in the present study. However, the respective quality of northern and southern Illinois forest habitat can be inferred from weight and antler beam data (Tables 1, 2 and 3).

Agriculture in JoDaviess and Carroll counties emphasizes beef cattle and dairy production (Table 4). Agriculture in the southern area is geared to cash-grain crops such as corn, soybeans and wheat (Table 4). There is no doubt that deer in both regions utilize agricultural crops as food, but, the chronology, types and degree of crop utilization are not known. Possibly agriculture oriented to beef cattle and dairying is more favorable to deer nutrition than cash-grain crops. In the northern counties hay crop acreage is primarily in alfalfa and alfalfa mixtures (92 percent), while southern county hay crop acreage reflects clover-timothy and other grasses (77 percent). The relative nutritional value of these species would favor alfalfa. Corn is the primary crop in both study areas. Deer utilize corn in both regions and it is apparent that the extent of corn acreage is considerably greater in the northern study counties, implying greater availability. It appears reasonable that these differences may be responsible, in part, for the measured difference between northern and southern Illinois deer by contributing differentially to the quality of the respective regional habitats.

Current deer havest levels on a county basis indicates that the northern area may be supporting a larger population than that of southern Illinois (Table 6). Because it is evident that there is considerably less forested area, and presumably less typical deer habitat, in the

TABLE 5.—Weighted average comparisons of soil characteristics for the soil associations of the northern and southern Illinois study counties[1].

Location	Soil Characteristics								Total
	Drouth Res.	Productivity	Parent Mat.	Thickness	Permeability	Slope	Surface Color	Silt Pan	
North									
Upland	3.0	2.2	3	3.8	3.5	2.5	2.3	0	20.3
Terrace	2.3	1.9	2	3.0	1.8	3.0	2.3	0	16.3
Bottom	3.5	3.3	3	2.0	4.0	3.0	2.5	0	21.2
South									
Upland	2.4	2.0	2.6	3.6	2.6	2.7	1.2	—.7	16.4
Terrace	2.8	2.4	2.0	2.9	2.7	3.0	1.6	—.4	17.0
Bottom	3.2	2.4	1.8	3.4	2.9	3.0	1.3	0	18.0

[1] Numerical equivalents for descriptive categories were established with the assistance of the SCS, Carbondale, Illinois. Maximum rate=25. Drouth Res.: Poor=1, Fair=2, Good=3, Very Good=4. Productivity: Low=1, Mod. Low=1.5, Moderate=2, Mod. High=2.5, High=3, Very High=4. Parent Material: Loess=3, Med. text. mat.=3, Sandy=1, Fine text. mat.=1. Permeability: Rapid=2, Moderate=4, Mod. Slow=3, Slow=2, Very Slow=1. Slope: 0-12%=3, 13-20%=2, 21%+=1. Thickness: 36-60"=4, 20-35"=3, 10-19"=2, <10"=1. Surface Color: Dark=3, Mod. Dark=2, Light=1. Siltpan or Claypan: Present=-1, Absent=0.

northern study area, the deer harvest suggests that the agricultural land-use practices are contributing to the maintenance of quality habitat. This effect probably reflects the contribution to available nutrition for deer and may be considered as a factor which increases the efficiency, or effectiveness of the northern habitat.

By comparison, southern Illinois has relatively more forested land, theoretically implying more available deer habitat; but, there is less agricultural supplementation because of the land-use practices. Possibly the effective carrying capacity may be more limited because of the lack of nutritional supplementation from adjacent or interspersed agricultural land. Further speculation on these relationships seem unwarranted until the relative significance of forest and agricultural land as deer habitat is investigated and population density data are obtained.

Soils

Soil fertility is the raw material by which wildlife is produced (Albrecht 1946). The quality and quantity of a wildlife crop is a direct reflection of such raw materials. In relation to deer nutrition, soils that vary in fertility differ in productivity. This difference can be extended to the nutritive value of the vegetation supported by these soils. Accordingly, habitat in the northern and southern Illinois study counties could exhibit qualitative differences in nutritive value of deer foods reflecting differences in soil fertility status.

Hundley (1959) investigated the available nutrients in deer-browse species growing on soils of different origin but was not able to detect clear trends and consistencies in the nutritive values of the plant species examined. However, in some instances the nutritive value of the same plant species was distinctly influenced by soil type.

The rating of soil characteristics revealed a disparity in the quality of northern and southern Illinois soil associations (Table 5). These differences may be reflected in the nutritive value of Illinois deer food and thus, could provide a partial explanation for the demonstrated difference in weight and antler development of northern and southern Illinois deer. Chemical analyses of soils and corresponding deer foods are needed before more meaningful cause and effect relationships can be established.

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TABLE 6.—Deer harvest trends for the northern and southern Illinois study counties.[1]

Year	North			South						
	Carroll	JoDaviess	Average	Gallatin	Jackson	Jefferson	Johnson	Union	Williamson	Average
1957	193	137	165	16	60	.....	15	173	41	61
1958	351	266	308	29	96	.....	29	264	80	100
1959	388	258	323	55	72	.....	56	228	84	99
1960	226	193	209	50	53	.....	67	135	90	79
1961	387	418	402	77	107	.....	131	222	163	140
1962	430	551	490	96	151	.....	224	288	226	197
1963	463	605	534	97	109	72	296	230	227	172
1964	337	465	401	113	109	37	310	254	254	180
1965	357	451	404	125	129	71	304	275	285	198
1966	329	373	351	72	78	71	281	226	253	164
1967	277	414	345	68	101	68	309	258	223	171

[1] Data from J. Calhoun (personal communication).

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DEER TRAPPING CORRELATED WITH WEATHER FACTORS

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ABSTRACT. — Deer (*Odocoileus virginianus*) trapping success on Crab Orchard National Wildlife Refuge was correlated with weather factors during the 1963-64 and 1964-65 winter trap periods. There was negative correlation with temperature and relative humidity during the former period and with rainfall during the latter period.

Trapping, although requiring fewer man-hours than most methods of deer capture (Hawkins et al. 1967), is expensive. Deer trapping results on the Crab Orchard National Wildlife Refuge (CONWR) from October 1963 through April 1964 and November 1964 through March 1965 are correlated with weather factors in an attempt to reveal the most appropriate conditions for success, thus reducing cost.

The study area was the approximately 18,000-acre, inviolate portion of CONWR. Four broad habitat types were dominant: cropland including fallow areas (27 percent), pasture (17 percent), brush (27 percent) and timber (29 percent).

METHODS

Deer were captured in corral and box traps placed in wooded areas and baited with shelled corn. Six corral and three box traps were used; however, not all traps were set each night. Because previous study indicated that corral and box traps yielded similar results in the capture of deer (Hawkins et al. 1967), data for each were combined for analyses.

Trapping was done on 130 nights during October 1963 through April 1964 and November 1964 through March 1965; however, data were deleted when less than three traps were set. As a result, 62 and 32 trapping nights were available for analyses for the former and latter periods, respectively.

Weather data were obtained from the following sources: temperature and precipitation, U.S. Weather Bureau station at Carbondale; barometric pressure and relative humidity, Climatology Laboratory, Southern Illinois University; and wind speed and direction, cloud cover and moon phases by the investigators. The U.S. Weather Bureau station and the Climatology Laboratory were located about 10 miles west of the study area.

The trap data were transferred to 80-column IBM cards. To eliminate redundant factors, a factor analytic technique (Harmon 1960) was employed on the 39 independent variables (Table 1) considered. The factors isolated in the factor analysis for each trap period were then submitted to a correlation and multiple regression analysis (MRA) against the dependent variable, trap success (percent of traps set that had one or more deer). The analyses were performed on an IBM 7040 computer in a stepwise fashion where the least

TABLE 1.—Independent variables possibly influencing trap success of leer or Crab Orchard National Wildlife Refuge, October 1963 through March 1965.

Variable Number	Description of Variable
1*	Average days traps open between settings
2	High temperature (F) day traps set
3	Low temperature (F) day traps set
4*	Range from high to low temperature
5	Change in high temperature from previous day to day traps set (plus temperature indicates rise while minus shows loss)
6	Change in low temperature from previous day to day traps set
7*	Change in high temperature from day traps set to next day
8	Change in low temperature from day traps set to next day
9	Rainfall (inches) day traps set
10	Snowfall (inches) day traps set
11	Snowfall accumulation (inches) day traps set
12	Rainfall day before traps set
13	Snowfall day before traps set
14	Snowfall accumulation day before traps set
15	Rainfall day after traps set
16	Snowfall day after traps set
17	Accumulation of snow day after traps set
18*	High relative humidity on day traps set
19*	Low relative humidity on day traps set
20*	Range from high to low relative humidity on day traps set
21	Change in high relative humidity from previous day to day traps set
22	Change in low relative humidity from previous day to day traps set
23	Change in high relative humidity from day traps set to next day
24	Change in low relative humidity from day traps set to next day
25*	High barometric pressure day traps set
26	Low barometric pressure day traps set
27	Range from high to low barometric pressure day traps set
28	Change in high barometric pressure from previous day to day traps set
29	Change in low barometric pressure from previous day to day traps set
30	Change in high barometric pressure from day traps set to next day
31	Change in low barometric pressure from day traps set to next day
32	Cloud cover
33	Wind speed (miles per hour)
34	Wind direction
35*	Moon phases
36	Barometric pressure 1800 day traps set
37	Change in barometric pressure from midnight to 1800 day traps set
38	Change in barometric pressure from 0600 to 1800 day traps set
39	Moon phases

* Deleted from 1964-65 trap period.

significant variable was dropped one at a time until only the most significant factor remained. Statistical analyses computed at each step included R-square, F-ratio, *t*-tests and levels of significance.

Results

1963-64 Trap Period

The 39 independent variables were loaded on 12 factors when the factor analysis was performed. The independent variable under each factor that contributed most to trap success was chosen for the MRA; these were 1, 3, 5, 7, 12, 17, 18, 24, 26, 34, 35 and 37 (Table 1). The MRA of the 12 independent variables showed that they contributed 36 percent to trap success ($R^2 = 0.36$, $P < 0.01$ with 49 df). Four of these (3, 7, 18 and 26) had significant *t*-test values ($P < 0.05$, 57 df), and acting together contributed 28 percent to trap success ($R^2 = 0.28$). Correlation of these factors revealed that they were all negatively correlated with the dependent variable, but only variables 3 (Low temperature (F) day traps set) and 18 (High relative humidity day traps set) had significant *r* values ($P < 0.05$; $r = -0.29$ and -0.30, 60 df).

1964-65 Trap Period

The 12 independent variables that contributed most to trap success during this period according to factor analysis were 8, 9, 10, 17, 20, 23, 28, 30, 31, 32, 36 and 39 (Table 1). MRA revealed that they contributed 39 percent ($R^2 = 0.39$) to trap success which was not significant ($P > 0.05$, 19 df). However, three of these (9, Rainfall (inches) day traps set; 10, Snowfall (inches) day traps set; and 36, Barometric pressure 1800 day traps set) acting together contributed 34 percent ($R^2 = 0.34$) to trap success ($P < 0.01$, 28 df). Of these, only variable 9 (Rainfall (inches) day traps set) had a significant *r* value ($P < 0.01$, $r = -0.48$ with 30 df) and contributed 23 percent ($R^2 = 0.23$) to trap success.

Discussion

The stepwise MRA for the first trap period suggested that, when considered together, a relatively low temperature and humidity and a relatively high barometric pressure were conducive to improved trap success; during the second period, rain hampered trapping, snow contributed to it and, as with the first period, a higher barometric pressure aided trapping. When considered alone, temperature and relative humidity were negatively correlated with trap success during the former period, while rainfall was negatively correlated during the latter period.

The average low temperature on days when traps were set was about 28 F (0-62) for each trap period. The average high relative humidity on days when traps were set was 86 (52-100) for the first period and 99 (96-100) for the second period affording little opportunity for correlation during the latter period. An average of 0.35 inches of rain occurred on 14 of the 62 trapping days (22.6 percent) during the first period, while an average of 0.56 inches fell on 8 of 32 (25 percent) days during the latter period, possibly accounting for the increased impor-

tance of rainfall to trap success during the latter period.

Temperature probably influenced trap success by altering the feeding preferences of deer on a daily basis. Observations have shown that on warm days, especially in late winter and early spring, deer feed on greens such as wheat and red clover in preference to bait corn; conversely, in the fall a relatively cold day induces feeding on bait corn although greens are still available. This may be an adaptation to conserve a positive energy balance as suggested by Moen (1968, p. 343) for deer in agricultural areas in Minnesota. Since trapping began earlier (October) and lasted longer (April) during 1963-64 than 1964-65, this influence was more pronounced during the former period.

High relative humidity and rainfall probably exerted their influence by restricting the activity of deer. Barick (1952) had better results in North Carolina when trapping just prior to low pressure storms. Hahn (1949) found that deer were most active during cloudless days of low relative humidity and as the relative humidity increased, deer movements decreased.

In conclusion, it appears that deer capture may be enhanced by trapping on relatively cold, dry days with a high barometric pressure.

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SIGNIFICANT MORTALITY FACTORS OF DEER ON CRAB ORCHARD NATIONAL WILDLIFE REFUGE

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ABSTRACT. — One hundred thirty-four (22 percent) of 601 white-tailed deer (*Odocoileus virginianus*) marked, released and subsequently observed on Crab Orchard National Wildlife Refuge during 1962-68 were known mortalities. Hunter harvests (49 percent) of deer that moved off the study area was the major loss while roadkills (28 percent) ranked second. Loss among yearling and older males average 20 percent through the 6 to 7-year class; that for corresponding females was 5 percent indicating a differential mortality rate bebetween sexes.

In a study of the population dynamics, ecology and life history of the deer on Crab Orchard National Wildlife Refuge (CONWR) from July, 1962, through December, 1968, an attempt was made to establish causes of known mortalities of marked deer. The study area included the approximately 18,000-acre inviolate portion of CONWR which supported an estimated population of 2,250 deer (Autry, 1967) in January, 1966, when a controlled harvest (Roseberry et al., 1969) yielded 1,109 deer of which 154 were marked.

METHODS

Four hundred sixty-three of the 687 deer (67 percent) during this study were 1½ years old or less when captured and marked (Hawkins et al., 1967*a* and *b*; 1968); aging was according to Severinghaus (1949). For record keeping purposes all deer were arbitrarily assigned a birth date of June 1.

Most information on mortality was afforded through roadkills and hunter harvests. Other losses were reported by people working in various capacities on or near the study area. When a mortality was discovered a cursory examination was made to determine cause of death when not obvious.

Percentage mortality by sex and age was determined using only deer marked and subsequently observed (601) rather than all deer marked (687). This eliminated from consideration deer that may not have survived capture or that lost markers.

RESULTS AND DISCUSSION

Six hundred eighty-seven deer were marked and released on the study area from 1962 through 1968; 601 of these (74 adult bucks, 125 adult does, 74 yearling bucks, 95 yearling does, 130 buck fawns and 103 doe fawns) were subsequently observed one or more times. One hundred thirty-four of the 601 (22 percent) were known mortalities during the study period.

The major mortality factor was hunter harvest which accounted for 49 percent of the loss (Table 1); since these deer were killed off the study area a high dispersal rate from

TABLE 1.—Aspects of deer mortality on Crab Orchard National Wildlife Refuge, 1962-68.

Sex and Age	Hunter Harvests		Roadkills		Dog Kills		Illegal Kills		Injuries		Unknown	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Male Fawn	.....	.....	2	5	3	33	.....	.....	.....	.....	2	11
Yearling Buck	32	49	12	32	.....	.....	.....	.....	.....	.....	2	11
Adult Buck	17	26	12	32	2	22	2	100	2	100	6	37
Female Fawn	1	2	2	5	3	33	.....	.....	.....	.....	.....	.....
Yearling Doe	5	8	4	11	.....	.....	.....	.....	.....	.....	3	16
Adult Doe	10	15	6	16	1	11	.....	.....	.....	.....	5	26
Totals	65		38		9		2		2		18	
Percentage Mortality by Cause	49		28		7		1		1		13	

CONWR was indicated. The most important non-hunting factor was roadkills; with the omission of hunter harvests, roadkills accounted for 55 percent of the mortality. November, which includes the main time of the rut, was the major period of such loss. Investigators in Maine (1954:1) contributed 45 percent of all non-hunting mortalities to cars and trains. Wilson (1956:4) reported such losses as 50 percent of all non-hunting mortality in New Hampshire; however, he felt this to be too high because of bias in reporting roadkills.

Dogs contributed 7 percent to the total mortality (Table 1); two-thirds of this occurred in 1964. At this time a concentrated dog removal effort was begun and over 100 dogs were collected during 1964 through 1966 (unpubl. data, Coop. Wildl. Res. Lab.). Most of the deer known to be attacked by dogs were in corral traps or were injured; dogs did not appear to be an important mortality factor of healthy, free-ranging deer. However, harassment was considerable in the winter of 1964-65 when the feral dog population was probably the highest. Although Progulske and Baskett (1958:191) considered harassment severe in Missouri, few deaths of deer were directly attributable to dogs. It seems likely that if the dog population had not been checked on CONWR it might have become an important mortality factor of even healthy deer as reported by others (Bennitt and Nagel, 1937; Shaw and McLaughlin, 1951; Barick, 1953; Ward, 1954; Brazda, 1957; and Wilson, 1954).

The cause of death could not be determined for 13 percent of the total deer mortality (Table 1). No loss could be attributed to parasites, diseases or malnutrition, but these aspects were not evaluated in detail.

Yearling and older bucks were predominant among hunter-harvested deer and roadkills (Table 1). This is explained by a higher dispersal rate and greater mobility of bucks, especially yearlings. About 80 percent of the yearling bucks disperse annually (unpubl. data, Coop. Wildl. Res. Lab.); of these, about 23 percent are harvested or otherwise mortalities off the study area (Hawkins et al. In manuscript). The majority of losses to dogs were fawns, suggesting their greater vulnerability. All illegal kills were adult bucks possibly showing selectivity for large antlered deer. Two deer found dead from injuries were adult bucks; the majority of deer in which the cause of death was unknown were adults.

For yearling and older bucks, the mortality rate averaged 20 percent through the 6 to 7-year age class (Table 2) whereas corresponding does, showed only a 5 percent loss. This differential mortality was manifested only for animals moving off the study area; there was no significant difference in loss between the sexes on the refuge. Field observations on CONWR show a substantial disparity of yearling and older bucks compared with corresponding does (unpubl. data, Coop. Wildl. Res. Lab.). Likewise, during a public controlled hunt on CONWR during January, 1966, a significantly higher proportion of the yearling and older deer harvested were does. Taber and Dasmann (1954:314) observed more doe than buck yearlings (100 to 64) in a population of black-tailed

TABLE 2.—Percentage mortality of deer by sex and age classes, Crab Orchard National Wildlife Refugee, 1962-68.

Age Class (Years)	Bucks		Does	
	Number Mortalities/ Number Marked and Subsequently Observed[1]	Percentage Mortality	Number Mortalities/ Number Marked and Subsequently Observed[1]	Percentage Mortality
0–1	7/132	5	6/109	6
1–2	46/179	26	12/175	7
2–3	23/98	23	7/170	4
3–4	11/53	21	5/131	4
4–5	2/18	11	3/94	3
5–6	2/11	18	5/56	9
6–7	2/9	22	0/27	0
7–8	0/6	0	1/16	6
8–9	1/1	100	0/2	0
9–10	0/0	0	1/2	50

[1] Includes a few that were not observed but for which the time and cause of death were known.

deer; they contributed this to a differential mortality rate of buck over doe fawns. Robinette et al. (1957: 12-14) reported a sex ratio of 3.04 does per buck in mule deer and contributed it to greater winter-loss among males.

Acknowledgments

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COMMUNITY METABOLISM IN LOWER PEORIA LAKE

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Abstract. — The diurnal oxygen curve method of measuring community metabolism was used to study primary production and community respiration in the Illinois River from June to September, 1968. Readings of temperature, conductivity. alkalinity, pH, turbidity, chlorophyll *a* content, and the euphotic zone were taken at regular intervals. Light intensity was recorded simultaneously with each diurnal and photosynthetic efficiency was computed.

Much work has been done on the extent and types of pollution in the Illinois River, but little has been recorded on the effects of this pollution on community metabolism.

Knowledge of community metabolism enables a better understanding of the aquatic community. Community metabolism involves production and respiration of oxygen by the community. For every gram of oxygen produced, approximately one gram of synthesized carbohydrate material is added to the aquatic community. Conversely, approximately one gram of oxygen is required for each gram of carbohydrate respired. Organic matter will accumulate in a community when production exceeds respiration as at Silver Springs, Florida, (Odum, 1957). When respiration exceeds production, however, there must be a constant influx of organic matter in order to maintain the community.

Description of Study Area

The stretch of river studied lies between mile 162.7 and mile 165.7 above the confluence of the Illinois and Mississippi Rivers (Fig. 1). This stretch of the river is approximately 3.0 miles in length and is called Lower Peoria Lake because of the river's natural widening at this point. The Illinois River is a very sluggish, silt laden, and enriched river which arises in Cook County and empties into the Mississippi River at Grafton, Illinois some 434 miles downstream. The silt load has been increasing since 1900 due to farming practices and to sewage and industrial outfall. At the same time, the river's rate of flow has been decreased by the building of a number of locks and dams.

Lower Peoria Lake was selected for the study area because it is believed to be one of the cleanest stretches of the Illinois River. Much of the effluent from Chicago and other communities upstream has had sufficient time to be degraded by the time it reaches Peoria. In addition, industrial and sewage outfall from

the Peoria-Pekin area enters the river further downstream.

Procedures

Two collection stations approximately three miles apart were established at opposite ends of the lake. (Fig. 1). Water samples for determination of physico-chemical conditions were taken approximately once a week at a depth of three feet to counteract wind and wave action. Water temperature was measured with a mercury thermometer. Conductivity was measured with a YSI Model 31 Conductivity Bridge at 25 C. Turbidity was measured in the laboratory with a Bausch and Lomb Spectronic 20 colorimeter with a 2.54 cm cuvettee at d_{450}. A Sargent pH meter was used for pH determinations. Methyl orange and phenolphthalein alkalinity were determined in the field by titration with 0.02N sulphuric acid.

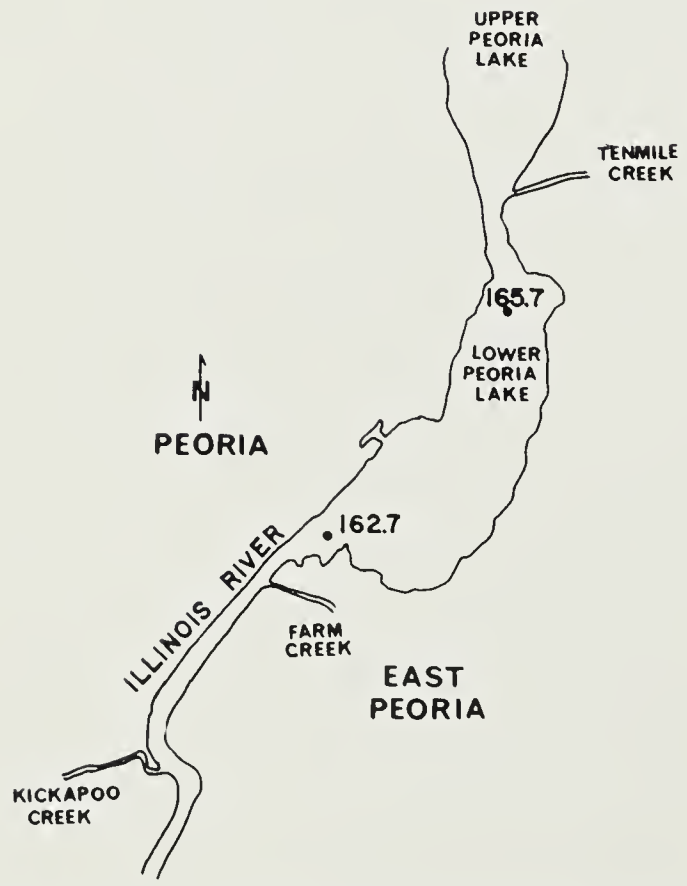

Figure 1. Map of Peoria Lake and the Illinois River near Peoria. Station locations are indicated by numerals. North Station = 165.7; South Station =162.7.

Water samples of 100 ml were filtered through membrane filters of 0.45 micron pore size for suspended chlorophyll analysis. The residues were extracted in 10 ml of 90% acetone for 24 hours at 5 C and centrifuged. Optical density was read at 665 millimicrons and 430 millimicrons on a Bausch and Lomb Spectronic 20 colorimeter. The methods of Odum, McConnell and Abbott (1958) were used to estimate chlorophyll *a* concentration where chlorophyll *a* in mg/liter of 90% acetone equals 13.4 d_{665}. When corrected for acetone and sample volume, this equation became 1.34 d_{665}.

Depth of light penetration was determined with a G. M. Mfg. Instrument Corporation submarine photometer. The euphotic zone was considered to extend to a depth at which light was 1% of surface intensity. A bimetallic actinograph kept at Bradley University measured solar radiation on days when community metabolism was measured.

Gross photosynthesis and respiration were computed from diurnal changes in concentration of dissolved oxygen according to the procedure of Odum and Hoskin (1958) and Copeland and Dorris (1962). Duplicate water samples were taken every two hours in daylight and every three hours at night at both stations and analyzed for oxygen by the Alsterberg (Azide) modified Winkler method.

Results and Discussion

Physico-Chemical Conditions

In most cases, mean summer

TABLE 1.—Mean Summer Physico-Chemical Conditions in Lower Peoria Lake.

Station	Temperature (C)	Turbidity (ppm)	Specific Conductance (umhos/cm)	Alkalinity		Dissolved Oxygen (ppm)	pH
				HCO_3^- (ppm)	$CO_3^=$ (ppm)		
North	25	66	540	179	0	6.4	8.0
South	25	67	539	179	0	7.9	8.2

physico-chemical conditions between stations were slight and insignificant (Table 1). Daily variation in water temperature was generally not more than 3 C while the seasonal variation ranged from 20 to 30 C. Alkalinity was due exclusively to bicarbonates.

Specific conductance ranged from 429 to 595 micromhos/cm. Conductivity below 537 micromhos/cm was not recorded except for a two week period when the river level was above normal due to heavy rains. The low readings may be attributed to dilution of river water by increased volume of runoff water.

The pH varied from 7.5 to 8.7. Most readings were above 8.0. Free carbon dioxide is absent or present in very low concentrations above pH 8.0. This may limit photosynthesis for some algae and higher plants while others are able to obtain their carbon dioxide from bicarbonates (Duffer, 1965).

Downstream pH values were always higher than upstream values with a single exception. Dissolved oxygen was also consistently higher at the South Station.

Turbidity ranged from 39 to 135 ppm during the study (Fig. 2). Highest turbidity observed was during a period of abnormally high flow in June.

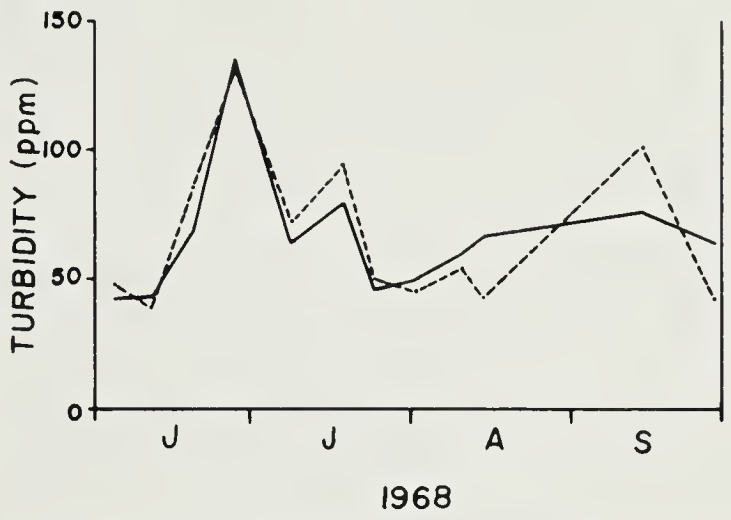

FIGURE 2. Turbidity conditions in Poria Lake (———) = North Station; (---) = South Station.

Chlorophyll *a* concentrations varied from 0.07 mg/l to 0.40 mg/l (Fig. 3). This parameter was converted to gr/m² by taking the prod-

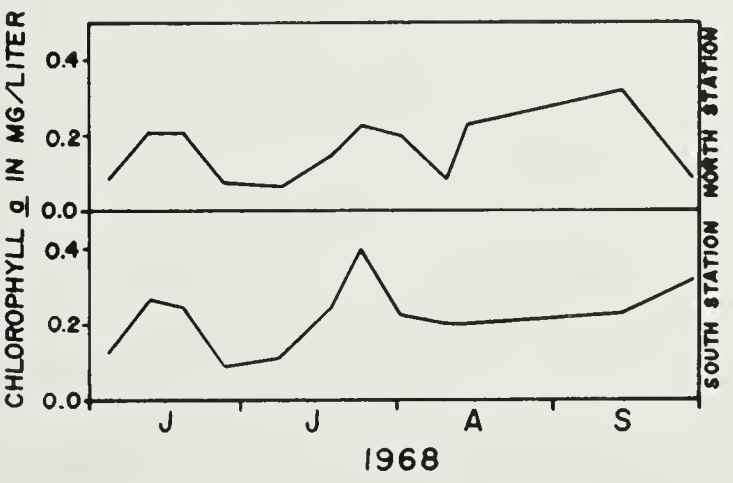

FIGURE 3. Chlorphyll *a* concentration in Peoria Lake.

uct of chlorophyll *a* concentration in gr/m³ and the euphotic zone (Fig. 4). Mathis, Root, and Weiman (1968) reported chlorophyll *a* concentrations in the Illinois River ranging from 0.03 to 0.50 mg/l. These concentrations are within the range of ecosystems receiving organic enrichment.

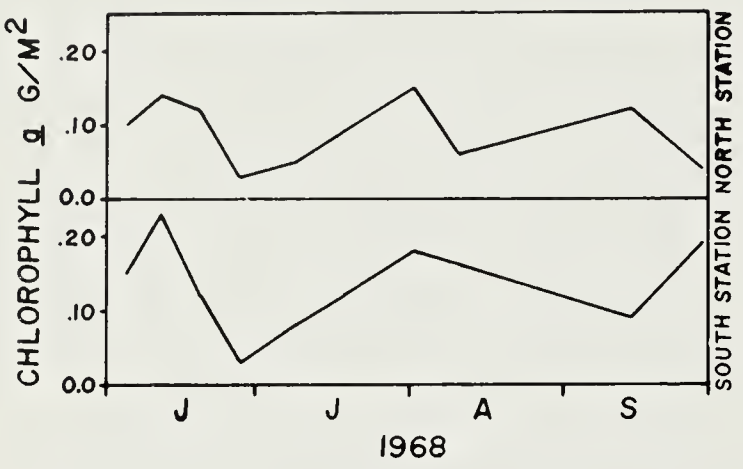

FIGURE 4. Chlorophyll *a* concentration in gm/m² in Peoria Lake.

The ratios of plant pigment absorbancies (D_{430}/D_{665}) are given in figure 5. Margalef (1963) used this ratio as a means of determining succession. As succession advances, the index increases. In general, the ratios for this study were near 3.0 except when the community was disturbed by high water conditions.

FIGURE 5. Margalef pigment ratios in Peoria Lake. (———) = North Station; (----) = South Station.

The ratios returned to around 3.0 shortly after normal flow conditions were re-established. Fluctuations in the pigment ratio were not so marked at the South Station indicating that it was probably less affected by environmental changes.

Community Metabolism

Eight diurnal analyses were performed at each station during this study. Flow rates were computed for each of those days and ranged from 10 hours on 28 June 1968 to 38 hours on 15 September 1969 (T. Butts, unpublished data). Primary productivity and community respiration were plotted for days with clear skies. Lowest production occurred at both stations during a time of high water, increased rate of flow and greatly increased turbidity. Gross photosynthesis ranged from 1.6 gm $0_2/m^2$/day on 28-29 June to 13.8 gm $0_2/m^2$/day on 6-7 June at the North Station (Fig. 6). Respiration at the North Station varied from 3.7 gm $0_2/m^2$/day on 15-16 September to 18.2 gm $0_2/m^2$/day on 6-7 June.

At the South Station, production ranged from a low of 2.0 gm $0_2/m^2$/day on 28-29 June to a high of 12.5 gm $0_2/m^2$/day on 6-7 June. Respiration ranged from 3.1 gm $0_2/m^2$/day on 15-16 September to 13.8 gm $0_2/m^2$/day on 29-30 July. Community metabolism in other aquatic communities calculated from diurnal oxygen curves is presented in Table 2.

Productivity in Peoria Lake is undoubtedly affected by the turbidity which in turn determines the euphotic zone (Table 3). The euphotic zone was generally deeper during

TABLE 2. Community metabolism in selected aquatic communities calculated from diurnal oxygen curves.

Source	g $0_2/m^2/day$ P	R
Eleven Florida Springs, summer (Odum, 1957)	0.68-63.8	
Blue River, Oklahoma, summer (Duffer and Dorris, 1966)	3.3-48.0	6.1-19.9
Skeleton Creek, Oklahoma, summer (Baumgardner, 1966)	4.2-29.4	17.0-57.1
San Marcos River, Texas, spring and summer (Hannan, 1967)	2.5-27.4	4.1-19.9
Illinois River (Present study)	1.6-13.8	3.1-18.2

TABLE 3. Depth of euphotic zone in meters.

Date	Station North	South
6 June	1.14	1.14
13 June	.69	.87
20 June	.56	.48
28 June	.33	.33
19 July	.76	.76
19 July	.58	.47
29 July	.88	.77
2 August	.77	.78
11 August	.70	.78
15 Sept.	.39	.39
29 Sept.	.46	.60
Mean	.66	.67

periods of low flow. Following heavy rains, however, the depth of the euphotic zone was minimal.

Photosynthetic Efficiency

The efficiency of algae in utilizing solar radiation for conversion to chemical energy was computed from gross photosynthesis and radiation data. Solar radiation was measured on five occasions and varied from a high of 674 cal/cm^2/day on 28-29 June, to a low of 495 cal/cm^2 on 15-16 September (Table 4). Efficiency was calculated according to the equation:

TABLE 4.—Photosynthetic Efficiency In Lower Peoria Lake.

Date	Station	Photosynthesis gm/m^2/day	Chlorophyll *a* gm/m^2	Photosynthetic Efficiency %	Total Solar Radiation cal/cm^2day
28-29 June	North	1.6	0.03	0.08	674
	South	2.0	0.03	0.10	
10-11 July	North	3.2	0.05	0.17	673
	South	4.3	0.08	0.22	
19-20 July	North	2.6	0.09	0.14	671
	South	4.3	0.12	0.22	
29-30 July	North	12.3	0.18	0.84	515
	South	12.4	0.18	0.84	
15-16 September	North	3.1	0.12	0.22	495
	South	2.2	0.09	0.16	

$$\text{Photosynthetic efficiency} = \frac{(0.35)\ (\text{gm } 0_2/\text{m}^2/\text{day})\ 100}{\text{solar radiation } (\text{cal.}/\text{m}^2/\text{day})}$$

This is assuming that 3,500 gram calories of solar radiation are required for each gram of oxygen. For the present study, a value of 50% light utilization was assumed (Ryther, 1956).

Efficiency was rather low and ranged from 0.10% to 0.84%.

Baumgardner (1966) obtained values ranging from 0.48% to 6.42% in polluted Skeleton Creek, Oklahoma. Copeland and Dorris (1964) reported efficiencies ranging from 0.0% to 3.9% in oil refinery effluent holding ponds. Efficiencies for undisturbed ecosystems are generally higher. Odum and Odum (1955) reported an efficiency of 6.0% for Eniwetok Atoll and Odum (1957) reported efficiencies up to 10% for eleven Florida Springs. In a study of two unpolluted southwestern streams Duffer and Dorris (1966) reported efficiencies ranging from 0.2% to 5.4% while Hannan (1967) reported a range of 0.2% to 4.8%. The greater diversity of flora in more highly balanced ecosystems is apparently the reason for the higher efficiencies. Algae in the Illinois River exhibited efficiencies similar to those observed in oil refinery effluent holding ponds in that both communities tended to utilize energy less efficiently than did algae in undisturbed systems.

Production/Respiration Ratio

The ratio of productivity to respiration provides a meaningful index by which flowing aquatic communities may be classified (Odum, 1956). When oxygen production exceeds demand, organic matter accumulates faster than it can be used and the community is said to be autotrophic. When oxygen demand exceeds production, organic matter is utilized faster than it can be produced and the community is said to be heterotrophic. In the later case, organic matter must be imported into the community if it is to survive. On only one occasion was the oxygen production greater than the oxygen utilization, and in general, the production to respiration values were low (Fig. 6).

The P/R ratio was generally higher at the South Station (Fig. 7). This was apparently due to greater

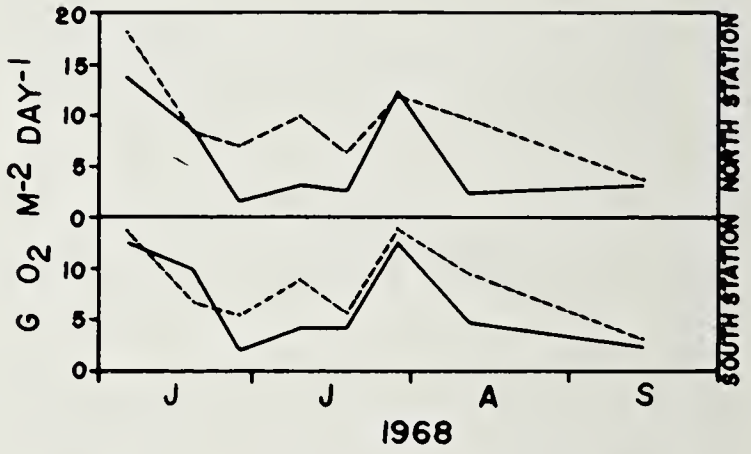

FIGURE 6. Community metabolism in Peoria Lake. (———) = Production; (---) = Respiration.

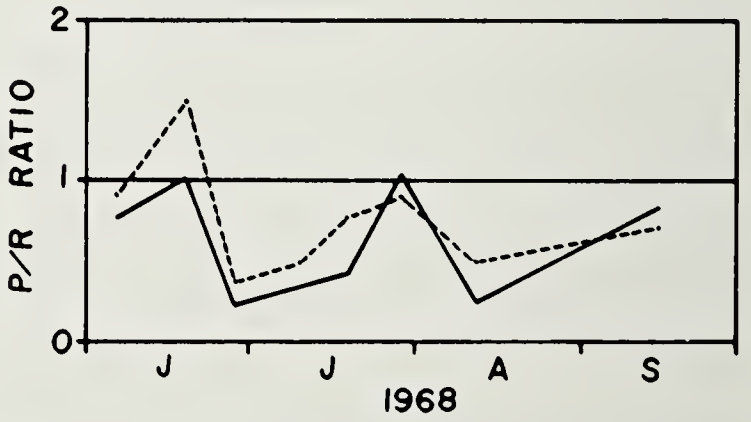

FIGURE 7. Photosynthesis/Respiration ratios of community metabolism in Peoria Lake. (———) = North Station; (---) = South Station.

community stability. During a study of the Moscow River, Kabanov (1961) found that production was depressed in waters polluted by industrial and sewage effluents. With the beginning of self purification, production and the P/R ratio increased.

Summary

Gross primary productivity in Peoria Lake was apparently depressed due to a number of reasons, the most important factor appearing to be depressed efficiency. Productivity was, however, similar to that which is found in the oxygen sag zone of many polluted streams.

Production-respiration ratios were usually less than unity indicating a heterotrophic community. Production at the South Station was somewhat higher than at the North Station resulting in a P/R ratio which was nearer to unity. This would seem to indicate a more stable environment.

Acknowledgment

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PRAIRIES IN THE PRAIRIE STATE

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ABSTRACT. — A map of the former prairies of Illinois, based on the original land survey records, is presented and compared with two earlier maps (Gerhard, 1857; Vestal, 1931). The new map shows more prairie than the two previous maps and more clearly delineates forested areas along major waterways.

A discussion of the major literature references that pertain to Illinois prairies is given. Evidence is given for the importance of fire in helping to maintain prairies in Illinois before white settlement.

The black prairie soils of Illinois have helped to make her one of the richest states in the nation. The biotic community of the prairie contributed to the making of this productive land. For over a half century scientific studies have been made of its plant life. This paper summarizes some of the relevant findings of these investigations and presents a new map of the prairies of Illinois. Early historic accounts have also been included inasmuch as they contribute to our understanding of the prairies.

White settlement in Illinois began in the southern part of the state with most of the settlers coming from Kentucky and Tennessee. These early settlers were hunters rather than farmers and in 1820 most of the people were located in the forested southern portion of the state. They were familiar with the problems associated with life in the forest but were inexperienced with the prairie. Their advance northward was primarily along wooded stream banks. Prairies were generally shunned by the earlier settlers for various reasons: the absence of trees was thought to mean that the soils were infertile, timber was needed for fuel and building material, running water was unavailable for livestock or mills, prairie lands lacked protection from winter storms, and the tough prairie sod presented an almost insurmountable problem to early agriculturalists.

Slowly, settlers encroached on to the prairie, but as late as 1836 those who thought the prairie habitable were considered part of the lunatic fringe. Log cabins were built along the edge of forested areas in preference to locations within the central parts of the prairies. Usually, the smaller prairies were inhabitated before the larger. The extensive grasslands remained essentially unoccupied until 1850, even though the settlers had learned how to successfully break the thick prairie sod and obtain high crop yields. The lack of efficient transportation systems, however, prevented the movement of crops profitably to distant markets. With the establishment of railroads in the decade 1850 to 1860, the prairies were rapidly settled. (Barrows, 1910).

Maps of the prairies of Illinois are available from several sources.

One of the earliest is that of Gerhard (1857). While showing the major prairies, his map is otherwise sketchy in detail. Vestal's (1931) map of the vegetation of Illinois, on the other hand, is more precise than Gerhard's and was based largely on information obtained from the State Soil Survey Reports (which include information on the distribution of prairie soils) and Telford's (1926) map of the forest for some Illinois counties.

The present research, based on the original land survey records, is intended to further contribute to our understanding of the prairie-forest boundaries in Illinois as they existed at the time of its initial settlement. Land survey records have been used by several investigators to determine presettlement vegetation patterns of other regions (Bourdo, 1956; Wuencher and Valiuna, 1967). A detailed map of the original prairie limits in Illinois may be of great value in solving phytogeographical problems, and will undoubtedly serve as a sound base for further ecological studies.

Methods

In the original land survey records, maps are available showing the extent of prairies and timbered areas within each township. These maps were drawn under the direction of the Surveyors General in the 1850's, although the original surveying in Illinois was completed before 1820. A complete set of township maps for this study was obtained on microfilm from the state Archives at Springfield. Many county courthouses also have copies of the survey records, as well as of the township maps.

Vegetation data was transferred to a base map of the state on which the townships were drawn in approximately one-half inch squares. Some of the non-forested areas in the original records were designated "barrens", "barrens or prairies", and "prairies." Both "prairies" and "barrens or prairies" were included on the map. While barrens are classified as grasslands, they are unique in floristic composition and lack some prairie plants such as *Silphium*. They are apparently established on forest soils rather than typical prairie soils, suggesting that at one time they were covered with forest (Vestal, 1936).

Results

Greater detail is shown by the present map of the prairie based upon original land survey records (Fig. 1) than by the two earlier maps (Barrow, 1910 (modified from Gerhard, 1857; Fig. 2) and Vestal, 1931; Fig. 3). Nonetheless, the broad outline of the three maps are similar. All depict the same major areas of prairie and timber along the larger rivers and streams. However, the new map (Fig. 1) not only shows many more prairie stands of exceedingly local distribution, but also tends to give more precise definition to the wooded areas along the waterways. Thus, the drainage patterns are more accurately delineated. The maps by Barrow and Vestal, on the other hand, show significantly less prairie in the south, southwest, and southeastern portions of the state. The southern boundary of the prairie as given in the new map, for example, approximates the limit of the

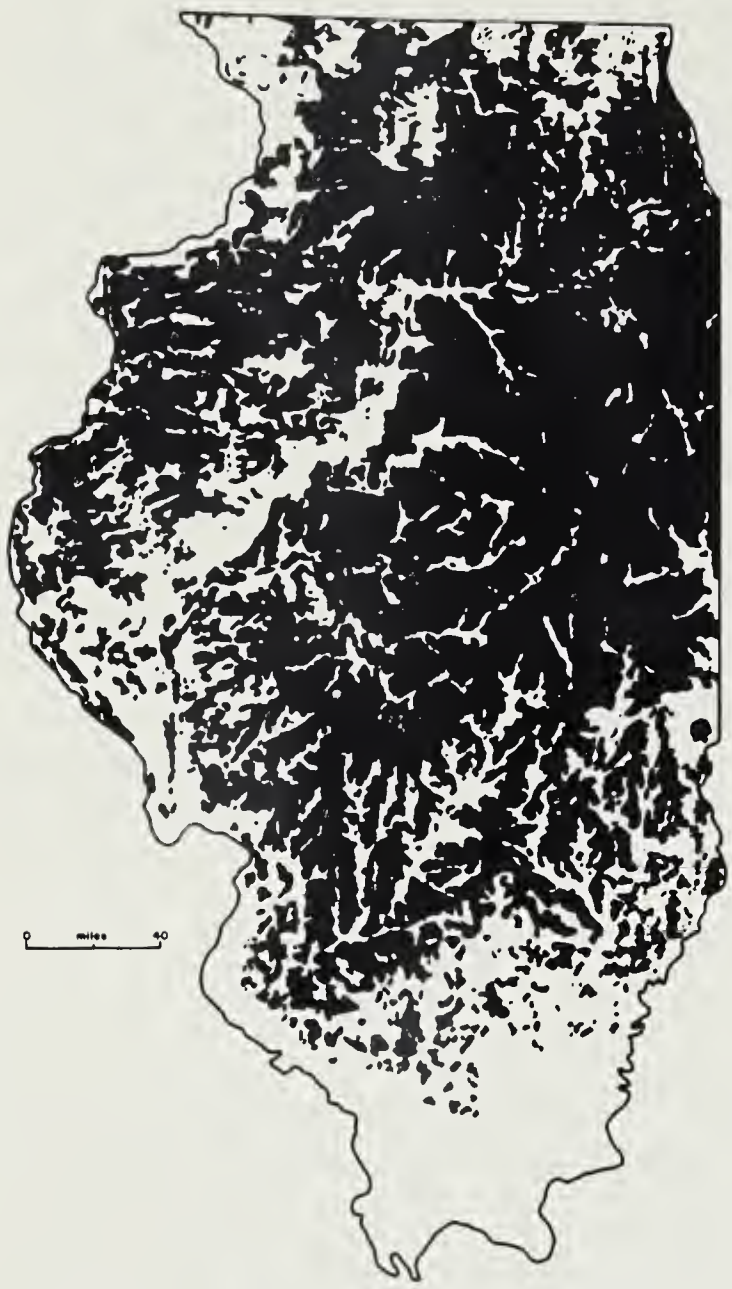

FIGURE 1. The location of prairies in Illinois at the time of settlement, 1810-20, based on the original land survey records.

FIGURE 2. Prairies in Illinois modified from Gerhard, 1857 (Barrow, 1910).

Illinoisan glaciation with no prairie occurring on unglaciated landscapes. None of the maps show hill prairies (cf. Evers, 1955).

It hardly needs to be emphasized that the new map presents the location of prairies during one time period only. Illinois has been the battle ground between the forest and the prairie for thousands of years (Gleason, 1923). It is thus easy to understand why Vestal's map, even though fairly detailed, shows less prairie than the present one based upon survey records. The boundary between the prairie and the forest is not static, but has continually shifted throughout the long history of these two major plant formations.

It may very well be that certain small areas of prairie had completely grown up to forest by the time Telford did his mapping, or possibly were completely destroyed by cultivation so that little evidence of the former prairie vegetation has remained. Areas that once supported small stands of prairie or very open savannahs were probably converted to closed forest within a fairly short

period of time after the cessation of annual fires (Vestal, 1931; Curtis, 1959; Vogl, 1964; Muir, 1965).

According to Gerhard (1857), "The first efforts to convert prairies into forest land were usually made on the part of the prairie adjoining timber . . . , three furrows were plowed all around the settlement to stop the burning of the prairies . . . , whereupon the timber quickly grows up. . . ."

It may never be possible to authenticate all of the small areas of prairie shown on the map based on surveyor's records. However, in southern Illinois there are historic accounts of small prairies in Williamson County (Allen, 1963); moreover, there are a few remnant prairie plants growing in some of these locations, although most of them have been destroyed by the plow or by urban expansion.

Several investigators have reported on the vegetation of the prairies of Illinois. According to Vestal (1914) and Sampson (1921), *Andropogon gerardi* was the dominant grass on the black soil upland sites, with *Andropogon scoparius* more important on the drier sites. Wet depressions supported *Spartina pectinata, Calamagrostis canadensis, Phragmites communis, Liatris spicata, Eryngium yuccifolium* and other species (Vestal, 1914; Sampson, 1921). Sand prairies along the Illinois River supported such xerophytic grasses as *Koelaria cristata, Bouteloua hirsuta* and *B. curtipendula* in prominent bunch grass communities (Gleason, 1919; Vestal, 1913). The hill prairies of Illinois were investigated by Evers, 1955; Kilburn and Ford, 1962; Kilburn and Warren, 1963; and Bland and Kilburn, 1966.

FIGURE 3. Vestal's (1931) map of the prairies in Illinois.

Gleason (1923) speculated about the history of the midwest prairie before the arrival of white settlers. During the xerothermic period species of the dry western regions, as well as many southeastern species adapted to the arid winter, became established. Among these southeast immigrants were numerous grasses that had the same vegetative form as the western grasses and easily mingled with them.

The increase in moisture associated with the close of the xerothermic period (Sears, 1942) was probably

more favorable to the spread of grasses of southeastern derivation than of western origin, and hence the latter were probably restricted to more arid sites. Gleason also notes that the four most important grasses in the Illinois prairies, *Andropogon gerardi, A. scoparius, Sorghastrum nutans,* and *Spartina pectinata* are still present today in the forested regions of the eastern states.

Tree growth was favored as the climate became more moist. Gleason hypothesized that much of the prairie of Illinois and the adjacent states would have grown up to forest cover if it were not for the aboriginal burnings that favored the grassland. The many accounts of the nearly annual burning of the prairie by Indians support his conclusions (Gerhard, 1857; Brendel, 1887; Muir, 1965). Carl O. Sauer (1950), recognizing the importance of man and his burning activities in influencing the distribution of the grasslands of the world, concluded that the grassland was a fire climax, and that man was responsible for most of these fires.

Gleason (1923) established the importance of prairie fires in determining the distribution of the forest along the major waterways of Illinois. Grass fires were generally swept from west to east by the prevailing westerly winds. Thus, the western borders of lakes and streams generally had less timber than the eastern sides.

That forest can invade prairie and prairie can invade forest is well documented by research studies and midwestern historic accounts (Vestal, 1918a; 1918b; Curtis, 1959; Shelford and Winterringer, 1959; Vogl, 1964). What is not well established is how important are factors other than fire in maintaining grassland areas within climatic regions that are also capable of supporting forests.

Transeau (1935) and Borchert (1951) point out that the climatic patterns of the prairie peninsula are clearly different from those of both the eastern deciduous and northern forests. Significantly, studies of the soil moisture conditions in this region during the drought period of 1933-34 by Britton and Messenger (1969) indicate that such dry periods are unfavorable for tree growth. Undoubtedly, periodic droughts coupled with repeated burning allowed the prairie to encroach into forest areas.

The effect of fire on the grasslands of the high rainfall areas of the midwest has been studied by several workers (Curtis and Partch, 1948; Ehrenreich and Aikman, 1957; Kucera and Ehrenreich, 1962; Kucera and Koelling, 1964; Hadley and Kiekhefer, 1963; Kucera *et al.*, 1967). Some found that productivity of the major prairie grasses was greater on burned than on nonburned areas (Hadley and Kiekhefer, 1963; Kucera *et al.*, 1967). Curtis and Partch (1948) report that burning aids the establishment of an artificial prairie by reducing bluegrass competition. Burning while the native grasses are still dormant, but while the introduced bluegrass is still green, retards the growth of bluegrass and promotes the spread of native species. The work of Hadley and Kieckhefer (1965) also supports their findings. The flowering of the dominant prairie grasses is also enhanced by burning (Curtis

and Partch, 1948; Ehrenreich and Aikman, 1957; Hadley and Kieckhefer, 1965).

The black ash surface resulting from fire increases the rate of spring warming on the burned prairie compared to non-burned areas. Removal of the mulch also increases the rate of warming, as well as reducing light and moisure interception, and aids in seedling establishment (Kucera and Ehrenreich, 1962; Lemon, 1967). However, the loss of the protective mulch layer can increase evaporative losses so that in arid regions of the grassland the beneficial effects of the fire are offset by low soil moisture conditions (Anderson, 1953; Dix, 1960). But in the high rainfall areas of the eastern arm of the prairie this does not seem to be the case. Kucera *et al.* (1967) reported a greater amount of production on burned than on unburned areas of Missouri prairies during periods of below normal rainfall.

Evers (1955) in his study of the hill prairies of Illinois concluded that these small grassland areas because of their exposure and topographic position will remain as prairies without fire, the xeric nature of the site being sufficient to curtail tree growth while favoring the xerophytic grasses.

Further work needs to be done on the effects of fire on the prairies of these xeric sites. Dix and Butler (1954), for example, showed that on a similar kind of prairie in Wisconsin burning decreased the cover of the dominant grasses the first year after they were burned. However, at least one study concluded that hill prairies will grow up to brush if they are not burned (Kilburn and Warren, 1963).

The extensive prairies of Illinois are now all but gone. There are, however, small strips of prairie still existent throughout the state along the railroad rights of way. In the past, these small areas of prairie remained because they received the same treatment they had before white settlement, annual burning (Leopold, 1948; Cottam, 1964). Many of these are beginning to disappear as they are put under cultivation, disked to control brush, or treated with herbicides. Some of these are beginning to grow up to woody vegetation.

The use of herbicides to control the "weeds" along the railroad rights of way would not appear to be a sound practice, especially in those locations where native prairie still remains. Because the prairie plants constitute a closed community, they prevent the growth of troublesome weeds along the railroad rights of way. Spraying destroys the established community and permits the invasion of weedy species. Native plants rarely become noxious weeds. A single season of cultivation will remove most of these species. Maintaining the prairies along the railroad and highway rights of way protects and improves the soils, provides a diversity of scenery, and helps to control weeds.

Conclusions

Previous maps of prairies in Illinois have failed to include many of the smaller prairies. Even though Vestal's map is fairly detailed it is incomplete in many areas, especially in the southern portions of the state.

Many of the smaller prairies disappeared after white setlement as a result of cultivation or the cessation of the nearly annual fires that retarded the growth of the forests, and thus are not shown on his map.

Many articles suggest that the prairie owes its origin to such factors as drought, soil conditions, exposure, grazing animals, and fire. While probably all contribute to the stability of the grassland, the evidence suggests that, for most of the flat land prairies of Illinois, fire was perhaps one of the major factors in presettlement times that contributed to its maintenance.

Acknowledgments

I would like to acknowledge Mr. John P. Crum who prepared the prairie map from the land survey records. Thanks are also due to William C. Ashby and Donald Ugent of Southern Illinois University for their suggestions for the manuscript. The final copies of the map were prepared by Southern Illinois University Cartographic Service. Funds for the research were provided by the Office of Research and Projects of Southern Illinois University.

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NOTES

USE OF BALLOON MODELS IN VISUALIZATION AND PREDICTION OF MOLECULAR SHAPES[1]

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Simple "sausage" balloons can be twisted together in the middle to make very effective models for the demonstration of coordinations of from 2 to 8 ligands. This method of presentation allows the demonstration of vibrational phenomena such as the inherent vibrational instability of square planar coordination with respect to tetrahedral coordination. These phenomena are difficult, if not impossible, to demonstrate with more conventional molecular models.

Four balloons twisted together in the the center demonstrate the square biprismate structure characteristic of eight ligands, e.g. IF_8^-. Breaking of one lobe of the octacoordinate model will cause collapse of the model into the pentagonal bipyramid of heptacoordination forming a model which can be used to represent e.g. IF_7 or XeF_6. The use of these models predicts, correctly, that XeF_6 is not a regular octohedral structure.

By successive removal of "ligands" the same model can be used for demonstration of successively lower coordination numbers. Among the interesting patterns which appear are a general pattern for the development of the coordination number patterns for 2, 4, 6, and 8 ligands, and the fact that five coordinated groups split naturally into a set of two and a set of three. The same splitting of a group of five is seen in the splitting of "d" orbitals under the influence of a magnetic or electrical field. Additional correlations and uses will be obvious.

The writer has found that lectures based on this material can, with appropriate modification, be used with profit and enjoyment with groups from grade school to graduate school level.

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A NEW PARASITE RECORD FOR OPILIONES (ARACHNIDA)

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A parasitized juvenile harvestman (*Opilio* species) was collected by the authors in a pitfall trap in an east-central Illinois deciduous forest between May 7-21, 1966, and a parasitic worm of the nematode family Mermithidae was observed protruding through the body wall of the opisthosoma (fig. 1). Removal of the opisthosoma and most of the prosoma revealed two juvenile specimens of a *Hexamermis* species which almost completely filled the harvestman's body (fig. 2).

FIGURE 1. Lateral aspect of *Opilio* species showing parasites protruding from body.

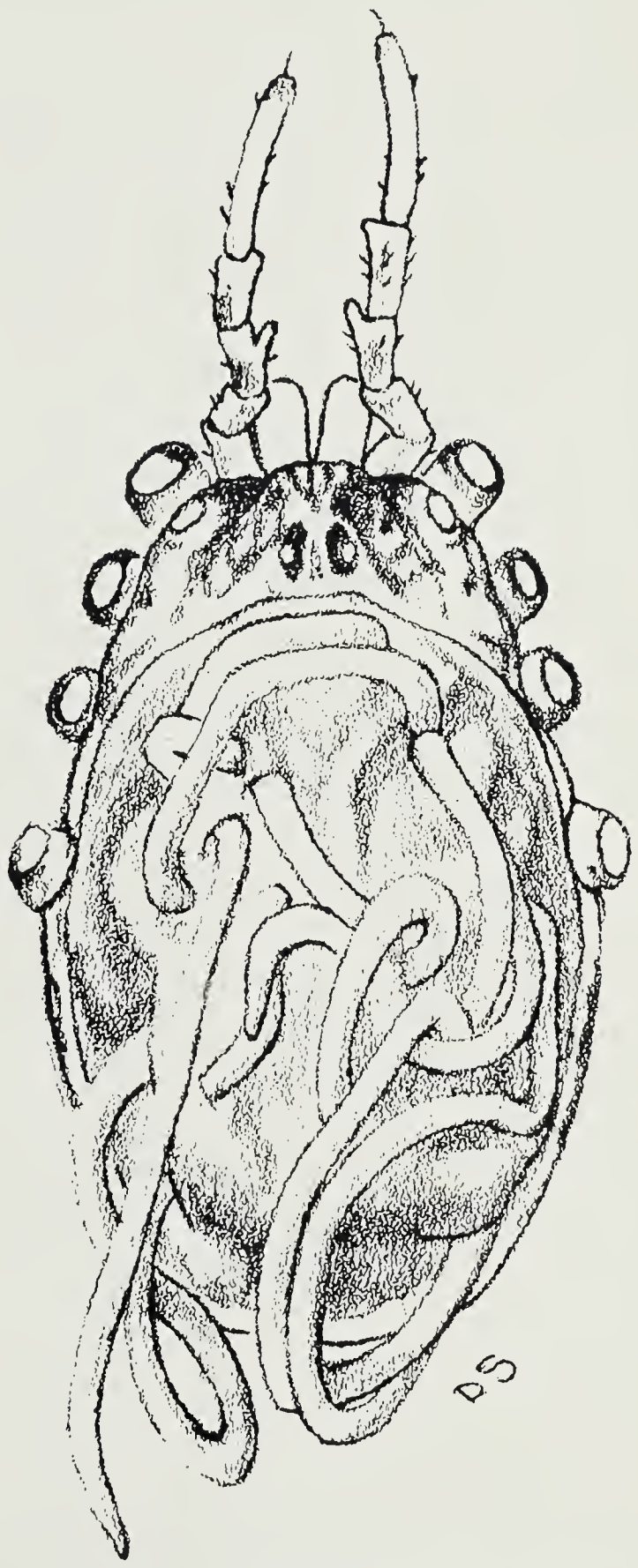

FIGURE 2. Dorsal aspect of same with most of prosoma and opisthosoma removed.

Mermithidae are generally parasitic in arthropods as juveniles. The juveniles usually leave the host before they mature and are free living as adults. Records of these parasites from Opiliones are rare in the literature. Until now only the genus *Mermus* (Kästner, 1928) has been recorded from harvestman. Spiders are the only other arachnids reported in the literature as being parasitized by *Hexamermis*. Kaston (1945) has recorded *Hexamermis* from the spider family Thomisidae, and Leech (1966) has recorded the genus from the families Thomisidae and Lycosidae.

The authors would like to thank Dr. Harold Welch for identifying the Mermithidae, Dr. R. F. Lawrence for bringing to the author's attention a little-known reference, and Mrs. Richard Slavens for making the illustrations.

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A MORAL CURRICULUM FOR BIOLOGY TEACHERS

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It is my opinion that in the past moral ideas have been neglected to a great extent in teaching biology, if by moral ideas we mean the following:

1. Teaching pupils *to conserve natural resources for the present and future benefit of humanity.*
2. Developing a *"reverence for life"* similar to that advocated by Albert Schweitzer.
3. Developing *humane techniques for research with animals.*
4. Teaching the principles of human reproduction and heredity *with special reference to the development of a responsible, personal moral code of ethics.*
5. Developing *habits of personal and group safety in the laboratory and field from the standpoint of being personally concerned with the welfare of fellow students as well as themselves.*
6. Encouraging pupils *to be concerned with the welfare of adults, including parents and teachers.*
7. Developing *honesty on all occasions, including evaluation activities.*
8. Developing *respect on all occasions for the viewpoints of others, including religious as well as scientific, political and other viewpoints.*
9. Developing *attitudes of respect for all, including the different races of mankind and different cultures, as well as self-respect and respect for the integrity of their own bodies and personalities.*
10. Developing *an overwhelming subscription to the value of truth in all of life's aspects.*
11. Encouraging pupils *to become aware of the social and moral implications of science and its applications, and of the necessity of their taking a personal stand on the issues arising from the applications of science in society.*

It seems obvious that such moral ideas may be taught in biology classes where the teacher is aware of the critical issues in science teaching today, such as those listed by the National Science Teachers' Association's Committee on Issues in February, 1969, in a paper prepared for distribution to science teachers. These issues were: (1) The importance of retaining and protecting natural resources for science teaching, (2) The responsibility of science teachers in deciding on the appropriate use of living animals in the classroom, (3) The importance of teaching about human reproduction, (4) The wise use of science exhibitions, (5) The liability of teachers for classroom accidents, and (6) The importance of cooperating in national assessments.

It also seems obvious that such moral ideas may be taught by teachers who make a direct attempt to incorporate them into their course of study and who are convinced of the importance of these ideas in their students' lives.

Where in the year's course of study for biology can these moral ideas best be taught? An examination of most general biology, zoology and botany textbooks, laboratory manuals and teacher's guides printed for use on different educational levels shows very little information dealing with such moral ideas. It is true that conservation is included as a topic for study in some books, and it is also true that the method of inquiry, stressing the values of truth and honesty, is emphasized throughout the various versions of the Biological Sciences Curriculum Study. These, however, are the exceptions, and even conservation as a subject is slighted in the BSCS versions and its fundamental importance is mostly implied rather than explicitly stated.

I would like to propose a biology curriculum which would incorporate directly class activities which would enable the pupils to learn these moral ideas and be moved by them in their lives.

Accordingly I have outlined a hpo-

thetical moral curriculum for one year for a biology class. This curriculum is organized in a chronological fashion based primarily on a seasonal approach of the study of life. The places where specific moral ideas (such as those I have listed) may be studied in this curriculum are indicated and the ideas underlined. Suggestions for developing evaluation techniques to measure pupil learning of these moral ideas are also mentioned.

An Example of a Moral Curriculum for Biology Teachers

1. *Introduction.* About 6 days.

In setting up classroom rules of conduct by teacher-student planning, and in arriving at class agreement on goals for learning and on methods of evaluating pupil progress toward these goals, *moral ideas could be discussed and included in the list of class objectives for the year. Class agreement could be reached upon the inclusion of evaluation techniques in the class activities. These evaluation techniques would attempt to measure pupil progress in learning these moral ideas and applying them in pupil behavior*, in addition to measuring progress toward other class-derived goals.

Since the pupils would hopefully actively participate in this curriculum planning, it would be assumed that they would have a "vested interest" in trying to learn and apply moral ideas in their lives in the school and neighborhood. Since they would also be participating in developing evaluation techniques, it can also be assumed that they would have a similar "vested interest" in scoring "high" when evaluated by these techniques. *All of the moral ideas which have been listed in this paper could be restated in the form of objectives presumably attainable by the pupils in the class. Both the teacher and the class, however, must be committed to their attainment.*

2. *The Study of Insects and other Animals in the Field and Laboratory.* About 4 weeks.

It can be assumed that through the study of these animals (taxonomy, life histories, morphology, etc.) the pupils would make a direct attempt *to learn to conserve natural resources, develop reverence for life, develop humane techniques, develop habits of personal and group safety, become concerned with the welfare, of adults, develop honesty, develop respect for the viewpoints of others, develop attitudes of respect for all, learn the value of truth, and become aware of the social and moral implications of scientific activities.* It can also be assumed that through the direct participation of these pupils in planning and evaluating their activities, they would desire to learn moral ideas, and that they would attempt to learn, retain and apply these moral ideas as they study these animals.

3. *How Plants and Animals Live Together.* About 3 Weeks.

It can be assumed that, through the active participatory study of these ecological relationships and principles, the pupils *would strive to learn and apply all of the moral ideas listed, with the probable exceptions of numbers three and four, concerning the learning of humane techniques for animal study and human reproduction, respectively.*

4. *How Plants and Animals Grow.* About 8 Weeks.

Likewise, through active, pupil participatory activities involving the study of the principles and relationships concerned with plant and animal growth (morphology, anatomy and physiology-including humans) it would be hoped that pupils *would learn and apply all of the moral ideas listed, with the probable exception of human reproduction.*

5. *How Plants and Animals Behave (or React).* About 3 Weeks.

Through the participatory pupil activities involving the study of organismal reactions to stimuli (including humans) hopefully the pupils *would learn to apply-humane techniques, develop a reverence for life, learn habits of personal and group safety, become concerned with the welfare of others, practice honesty, respect everyone (including themselves). be truthful, and develop an awareness of the social and moral implications of science and its applications.*

6. *How Plants and Animals Reproduce.* About 4 Weeks.

Through the study of reproduction the pupils *might learn and apply all of the moral ideas which I have listed, and especially the moral idea of developing a responsible, personal moral code of ethics with respect to the facts of human reproduction.* It is very likely that the

manner of teaching the facts of human reproduction and of encouraging pupils to develop such a personal moral code would be influenced by social pressures. In some instances it might not even be possible to teach these facts and ideas because of negative pressures from the community. In any case, to teach these very important things there probably would need to be constructive and intelligent administrative and community cooperation in planning and facilitating activities aimed at pupil attainment of these objectives.

7. *How Plants and Animals Come to Be As they Are (Heredity and Evolution).* About 5 Weeks.

Through class activities based on learning the principles and theories of heredity and evolution pupils *could learn and apply all of the moral ideas listed.* In some communities the cooperation and support of the school administration, parents and others in the community might be vitally necessary to insure success in the study of genetics principles and evolutionary theory, especially as these are related to humans. In some communities it might be impossible to study the human aspects of these fields. Teachers and administrators should show leadership, tact, perseverance, perceptiveness, discernment and objectivity in order to carry these studies through to a successful conclusion in the class.

8. *How Man Lives With Plants and Animals.* About 4 Weeks.

Studying the basic principles of conservation could provide class activities through which pupils *could learn and apply all of the moral ideas listed.* Since the studies of pollution and human conservation may be included in this portion of the curriculum, problems associated with an expanding human population could well be studied in planning and executing class activities.

9. *Plants and Birds in The Field and Laboratory.* About 3½ Weeks.

In the study (identifications, taxonomy, morphology, etc.) of this final phase of the curriculum *all of the moral ideas which have been listed could be learned and applied with the probable exception of human reproduction.*

In conclusion, it should be emphasized that the curricular approach advocated here reflects my faith in teaching democracy in the biology classroom by encouraging, aiding and abetting active pupil cooperation in planning and executing the activities of the class, including evaluation. Evaluation techniques could include behavior checking, anecdotal and other records, interviews, reports, questionnaires, information tests, interest tests, aptitude tests, attitude tests, "opinionnaires", forms given other teachers and parents, guide sheets, laboratory and project work, tapes and television reports of class work, and letters of recommendation.

It is my firm belief that a biology teacher who has a thorough knowledge of both his subject and his pupils, and who is committed to teaching his pupils important biological principles, concepts, interesting facts and applications in ways meaningful to his pupils, would experience little difficulty implementing this curriculum. This moral curriculum would then become an integral part of the total biology curriculum, and hopefully all engaged in its planning and execution would benefit personally by gaining not only knowledge, but also wisdom and, adding to their wisdom, *understanding.*

Manuscript received January 14, 1970.

PRESIDENT'S REPORT: THE ILLINOIS STATE ACADEMY OF SCIENCE: PROGRESS AND OPPORTUNITY: 25 APRIL, 1969

WILLIAM C. ASHBY
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I should like to share with you my thinking on the role of the Academy in science and education. Our objects are the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the science interests of the state. We promote scientific research through our modest research grants program, which we have expanded in recent years and hope to expand still further. We also promote research and diffuse scientific knowledge greatly through the annual meetings at which research reports are presented, and through the publication of research papers in the Transactions. Here again the Academy has made gratifying progess in recent years and continues to sustain this role.

The diffusion of scientific spirit and the unification of the science interests of the state are advanced through several activities of the Academy. All major disciplines in science are represented in one or more of the sections, and in the breadth of coverage to be found in the Transactions. The importance and role of the Academy varies from one discipline to another. All sections have been confronted with the question, whom do we serve? For some disciplines the Academy section serves as a central focus of interest and activity. In other disciplines regional subdivisions of national organizations have been developed. Parent organizations have become larger and larger, and thereby lose much of the informality and the focus of interest treasured by workers in a field of study. The proliferation of scientific groups and scientific meetings leads to multiple demands for an individual scientist's time in attendance, and even for meeting dates. The Academy must continually redefine its role in keeping with these changes.

The future of science lies in the young people who are attracted to it and enter professional life as scientists. The Academy founded and presently cooperates with the Illinois Junior Academy of Science in its programs with high school students and teachers. Our Central Office Committee, chaired by Dr. Yohe, is nearing completion of plans for an Executive Officer to serve both Academies and to strengthen their effectiveness. We plan to secure "starting-up" costs for the first five years from interested foundations. By the end of that time increased memberships, industrial contributions to expanded programs, overhead from grants, and other new funds should enable the Academies to be self-supporting financially, with greatly expanded programs. The Michigan Academy recently took this step and was supported by the Kellogg Foundation and by institutional memberships from the state universities.

Interest in science, and in research projects, by high school students are fostered by the Illinois Junior Academy of Science. The Academy Visiting Lecturer program, headed by Dr. Rolf, brings research persons to high schools for talks and discussion. Our present volunteer program is supported by modest Academy funds. With the new Central Office we hope to establish funding equivalent to the former National Science Foundation grant program, and to enlarge greatly the Visiting Lecturer program for high schools.

Existing institutional programs for graduate training in science are heavily committed to research. In contrast, undergraduates spend almost all of their time and energy completing a major. A curious fact of undergraduate training is that, unlike high school and graduate school, there is often little oppor-

tunity for research. Some universities may provide research experience as a student worker for a few students. Many schools, particularly 2- and 4-year colleges, do not offer such opportunities. The Academy council has been interested in possible ways to undertake expanded activities at the undergraduate level. Some states have developed successful collegiate academies. Collegiate academies provide a forum for developing science and research interests, may sponsor seminars, conferences, and publications, and conduct trips for undergraduates to laboratories and field areas. Our Academy may wish to encourage the formation of collegiate sections as means of reaching the rapidly expanding numbers of students and faculty persons in junior colleges and other new institutions. Our collegiate section in chemistry is presenting a program today.

Another way in which the Academy can contribute to science training of students in high schools, and in colleges and universities, is through advising and representation on committees, boards, and councils concerned with teacher preparation and accreditation. An important need is articulation of science courses in the rapidly growing number of junior colleges with the programs of 4-year colleges and universities. Both our Science Teaching and Accreditation and Certification committees have this past year sent delegates to groups and meetings concerned with teacher training and with science requirements in Illinois. My understanding is that decisions are largely made by education groups, and that the Academy is not presently in a position to do more than offer advice when asked. I hope that with continued effort the Academy will be able to speak more effectively on the needs for science preparation of teachers, and the requirements for science courses in the schools. The science teaching committee has invited Dr. Browne as our keynote speaker today in keeping with the active interest of the Academy in the contributions of science to education at all levels.

During the past few weeks another opportunity for service has been made known to the Academy. The Director of Research of the Illinois Legislative Council has written to inquire about the possibilities of a survey which could identify college and university scientists who would be willing to work with legislators in developing solutions to particular problems, such as strip mining. We have responded enthusiastically and are moving ahead with plans to make this type of service available to the legislature. You will learn more of these plans at our business meeting this noon, and through announcements.

In conclusion, I feel that the Illinois State Academy of Science has made significant and continuing contributions to science in the 62 years since its founding. New opportunities now await us. The office of Executive Officer will greatly strengthen and expand our effectiveness. Programs to reach the newly emerging schools are needed. Representation and consultation on educational and governmental problems will be of direct benefit in science areas. I look forward confidently to a strengthened and expanded program of service in science by the Academy.

Manuscript received February 11, 1970.

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ISAS PRESIDENT'S MESSAGE, 1970

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The outgoing President of the Academy is charged with presenting a "state of the union" message which points up the contributions of the past year, the unfinished business, and the hopes for the future.

The goals of the Academy must involve an effective concern for the whole of our society, its environment, and the growth of the individuals who make it up. This involves some bewildering questions and the Academy is not yet prepared to become engaged in finding solutions for all of them.

We have been fairly successful in helping to advance the professional growth particularly of the young scientist. Our journal, the Transactions, is a medium well suited for their publications. This year a new editor has performed very admirably with a capable staff. We remain fortunate in receiving a subsidy from the state legislature.

The annual meeting provides another forum of expression and we are this year still experimenting with a somewhat revised format that I trust will be well received. The meeting is one good way to favor communication among scientists from all parts of the state.

The Academy has continued to foster research in another small way by awarding some grants-in-aid. This has approximated $1,400 and represents seed money to stimulate the younger researcher.

We have continued our practice of selecting Illinois students for state honorable mention from those who entered the Westinghouse Science Talent Search.

I have mentioned the responsibility of the Academy in regard to our environment. Pertinently, we have this year established a liaison between the Academy and the legislature, but this is a first step. It appears to be in the nature of an individual conference between a legislator and a scientist.

In another direction, we have continually submitted resolutions to the governor, the state legislature and the National Congress about bills of scientific interest. I can only say subjectively that these have played a part in producing favorable legislation.

We have a Committee on Conservation and one on Archaeological and Historical Sites which are vigorous and alert. These activities have every reason to be continued. Our Committee on Animal Experimentation in Research is well constituted and has always been active.

It has been suggested (1) that Academies establish a science advisor to the governor and an advisory committee like that of the presidential science advisor and his committee;

(2) that Academies conduct science seminars on relevant problems for members of the legislature or even county boards; and (3) that Academies appoint committees to study problems relevant to science at the state level.

More exploration is needed with the Illinois Commission on Technological Progress. This body has worked on a bill which established an Illinois Science Advisory Council. The Commission has recommended the establishment of a Science Advisor to the Governor and it has conducted hearings probing the impact of science and technology upon state and local communities. There is much to be gained by a meeting between the Academy and the Commission.

One might add the suggestion that Academies publish newsletters directed to the general public. The scientist must communicate his tested opinions on matters affecting science. Our function as a communicator of science has been relatively neglected.

We have at the outset voiced a concern for the whole of our people in Illinois. Our Academy has involved itself in this goal partly by its concern about science education. The NSF Visiting Lecturers Program, in which the Academy has participated, serves not only to bring lectures to high school students, but brings strength and recognition to the Academy. The loss of the financial support in this past year has seriously hampered this activity and we must come to some conclusion in the immediate future as to its continuance.

Academies tend to think of ways in which they can assist elementary and secondary school programs in science. Some very poor teaching in science occurs at the collegiate level and the Academy might contribute effectively to the improvement of course content at this level. Our Committee on Science Teaching is far from inactive in this regard.

I must now turn to a report of the progress of internal organization. I believe that we have a sufficiently strong fiscal organization providing for strict budget control and expenditures of monies. This involves the Council, Treasurer, Budget Committee, and the Committee on Legislation and Finance. Funds are being actively solicited by a Contributing Membership Committee whose powers of solicitation have been broadened by the Council, and this Committee may well be one factor in taking us out of the stage of a "hand to mouth" existence.

The modernization of our planning led to the creation of a Permanent Central Office Committee, whose first duty was to find sources of funds for a paid executive secretary. This Committee has encountered serious difficulties in this year of its operation. We have fortunately been able to induce a new chairman to assume the responsibilities for one year and we hope that he may formulate a successful approach.

I am not pessimistic about eventual success. A paid executive is essential to public relations, improved fiscal control, better administration, and the highly important function of fund raising.

The Academy should have a method for looking at itself through its own history. The position of Historian was established many years ago,

but it has not been filled recently. I have succeeded in finding a person whose name I have submitted to the Nominations Committee. Certainly, the data relative to pioneers in scientific work in Illinois should be recorded to avoid their permanent loss.

In the process of internal planning the Academy must have a mechanism for continual self analysis. The Planning Committee has this past year proposed several constitutional and bylaw changes and has more efficiently delineated the duties and relationships of our other internal committees.

The Academy has maintained its affiliations with the A.A.A.S., and especially with the Illinois State Museum. The latter association has brought much satisfaction to the Academy.

All told, the year has been personally rewarding. I have received full support from the officers and the Council, and the Academy may feel confident of continuing success with dedicated scientists guiding it.

Manuscript received April 27, 1970.

THE RESIDENT MAMMAL AND BIRD POPULATIONS OF A SAND PRAIRIE AND FOREST NEAR BATH, ILLINOIS

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Abstract. — A unique sand prairie and scrub forest on the Wilkinson Farm, near Bath, Illinois, was studied in 1968 for an analyis and measurement of the vegetation and of the mammal and bird populations. The prairie was dominated by *Andropogon scoparius, A. furcatus, Stipa spartea, Koeleria cristata,* and *Panicum pseudopubescens.* The dominant trees were *Quercus marilandica, Q. velutina,* and *Carya ovalis.* The small mammals, *Peromyscus leucopus, P. maniculatus,* and *Microtus ochrogaster,* were about equally abundant in the prairie as in the forest, although only *P. leucopus* occurred in the forest. Only 17 bird species nested in the sand prairie and forest. The Field Sparrow, *Spizella pusilla,* and Lark Sparrow, *Chondestes grammacus,* were the most numerous species in the sand prairie and the Bobwhite, *Colinus virginianus,* and Tufted Titmouse, *Parus bicolor,* in the forest. Although the small mammal populations were considerably higher than the bird populations, population densities of both mammals and birds were very low compared with other non-sandy areas in Illinois.

During the spring and summer of 1968, an inventory was made of the vegetation and of the mammal and bird populations in the north half section of the Wilkinson Farm, recently acquired by the Illinois Department of Conservation for a possible future Nature Preserve. The Wilkinson Farm is located nine miles south of Havana, Illinois, between the towns of Bath and Kilbourne. This study is part of a research program at the University of Illinois designed to compare the productivity of a poor habitat with the characteristically highly fertile habitats occurring elsewhere in Illinois. The entire sandplain is about 14 miles, 22.5 kilometers, wide; 75 miles, 120.8 kilometers, long; and has a total area of about 179,200 acres, 72520 hectares, most of which is found in Mason County (Vestal, 1913). Previous studies on sand prairie in this vicinity have been done by Hart and Gleason (1907), Gleason (1910), and Vestal (1913).

The sand prairie is made up of bunch-grasses, numerous forbs, and blowsand openings.

Common grasses are:

Andropogon scoparius Michx., little bluestem
A. furcatus Muhl, big bluestem
Stipa spartea Trin., porcupine grass
Koeleria cristata (Linn.) June grass
Panicum pseudopubescens Nash, switch grass

Common forbs are:

Baptisia leucophaea Nutt.
Lithospermum croceum Fern.
Viola pedata L.
Coreopsis laceolata L.
Krigia virginica (L.) Willd.
Erigeron strigosus Muhl.
Rudbeckia hirta L.
Opuntia rafinesquii Engelm.
Commelina erecta L.
Oenothera rhombipetala Nutt.
Euphorbia corrollata L.
Asclepias tuberosa L.
A. verticillata L.

A. amplexicaulis Sm.
Fragaria virginiana Duch.
Specularia perfoliata (L.) A. DC.
Tephrosia virginiana (L.) Pers.
Potentilla simplex Michx.
Rosa carolina L.
Antennaria plantaginifolia (L.) Richards
Polygonatum biflorum (Walt.) Ell.
Smilacina stellata (L.) Desf.
Verbena stricta Vent.
Helianthemum canadense (L.) Michx.
Phlox bifida Beck
Penstemon pallidus Small
Myosotis verna Nutt.
Tradescantia canaliculata Raf.
Chrysopsis villosa (Pursh) Nutt.

The scrubby forest consists chiefly of blackjack oak, *Quercus marilandica* Muench (61% of stems 3 inches, 7.6 cm, or more in diameter, 50% of total basal area), black oak, *Q. velutina* Lam. (28%, 46%) and sweet pignut hickory, *Carya ovalis* (Wang.) (11%, 4%). The total number of trees per acre average 430, 1063 per hectare, and their total basal area, 9220 square inches, 59,484 square centimeters. These measurements are based on an analysis of eight equally spaced square plots, each 50 meters, 164 feet, on a side.

This study was submitted as a thesis for a Master of Science degree at the University of Illinois. I wish to thank Dr. S. Charles Kendeigh, my advisor, for aid in analyzing and presenting the data; James R. Karr, Roland Roth, and Charles Blem, graduate students, for helpful discussions; Dr. Donald F. Hoffmeister for assistance with mammal identifications; and Dr. Robert A. Evers for assistance with plant identifications.

Mammals

Mammal censuses were taken concurrently in the forest interior and on the sand prairie from 12 July to 19 July, 1968. Fitch (1950) live-traps were used and individuals captured were identified by toe-clipping and then released. The traps were placed in a circular grid pattern to maximize the area to circumference ratio and minimize the influx of animals from the outside. Each circular area contained 129 live-traps and covered 6.53 acres, 2.6 hectares. The traps were set at appropriate locations approximately 45 feet, 13.7 meters, apart. There was a total of 2064 trap nights.

Three species were taken in the sand prairie. Fourteen white-footed mice, *P. leucopus,* were taken a total of 30 times in the sand prairie; five deer mice, *P. maniculatus,* for a total of 20 times; and three prairie voles, *M. ochrogaster,* for a total of seven times. Male *P. leucopus* outnumbered the females ten to four.

Only one species, *P. leucopus,* was taken in the forest. Seventeen individuals were taken a total of 34 times, and again, there was a preponderance of males, ten to seven.

The locations of the captures were recorded and mapped. *P. maniculatus* individuals were more centrally located in the grassland, while *P. leucopus* captures were peripherally adjacent to the forest-edge. It appears likely that as trees continue to invade and replace the grasses, *P. maniculatus* will disappear.

Maximum distances between recaptures, which may provide some indication of the size of home ranges, average 68 feet, 20.7 meters, for *P. leucopus* in the sand prairie and 128 feet, 39.5 meters, in the forest-interior and for *P. maniculatus* in the sand prairie, 146 feet, 45 meters.

Four different methods were used for calculating population densities (Table 1). The calculation after Will (1962) divides the total number of individuals taken by the actual area trapped. The Blair (1941) calculation adds a buffer strip to the circumference of the trapping area equal to one-half the width of the average home range of the individuals captured more than once. This acreage is then divided into the number of individuals captured. The density determination after Stickel (1946, 1954) subtracts a buffer strip one-half the average maximum distance between traps in which individuals were captured four or more times during a 7-day (8 days in this study) trapping period. Animals taken in both the central area and buffer strip are counted, divided by two, and added to the number taken only in the central area, and the density is then calculated using the acreage of the central area. Blem (1968) considers the two outer rows of traps to make up a boundary strip. Those animals caught only in the boundary strip and obviously with the greater portion of their home range outside the grid are eliminated from the density calculation, while individuals caught in both the boundary strip and central portion of the grid are included although their home ranges may also extend outside the grid. The entire trapping area, including the boundary strip, is used in the density calculation. The population density was estimated by the Lincoln Index, grouping the first four days as marking days and the last four as recapture days.

Population densities calculated by these four methods show considerable discrepancy and there is no sure way of telling which is most reliable. Densities based on Will's methods are the highest as no correction is made for portions of home ranges extending outside the trapped area. However, there is very little agreement or consistent difference between densities calculated by the other three methods where corrections are attempted for peripheral animals. The averages of the four methods of calculating the densities give at least some idea of the relative abundance of the different species in the two areas. The total number of small mammals in the sand prairie, 244/-100 acres (40 hectares), is about the same as in the forest-interior, 256/-

TABLE 1. Small mammal population densities per 100 acres, 40 hectares.

Area	Species	Method of Calculation				Average
		Will	Blair	Stickel	Blem	
Sand Prairie	*P. leucopus*	214	104	65	214	149
	P. maniculatus	77	43	66	61	62
	M. ochrogaster	46	37	.....	15	33
Forest	*P. leucopus*	260	95	454	214	256

100 acres. The number of small mammals in the sand prairie is 1.6 times the number of birds; in the forest-interior, 8.5 times greater. Will (1962) found only 80/100 acres (40 hectares) *P. leucopus* in a deciduous forest of south-central Illinois. Blem (1968) obtained 260/100 acres (40 hectares) during July in upland deciduous forest in east-central Illinois. However, Kendeigh (personal communication) finds very much larger populations both in prairie and forest on the black soils of east-central Illinois. All three investigators also found the short-tailed shrew, *Blarina brevicauda* present, although it was absent on the sandy areas.

Besides the two species of *Peromyscus* and the prairie vole, other species observed in the general area include the eastern fox squirrel, *Sciurus niger;* red fox, *Vulpes fulva;* eastern cottontail, *Sylvilagus floridanus;* white-tailed deer, *Odocoileus virginianus;* and raccoon, *Procyon lotor.*

Birds

Bird censuses were taken in the grassland (50 acres, 20 hectares), on the forest-edge (57.5 acres, 23 hectares), and in the forest-interior (40 acres, 16 hectares). The grassland and forest-edge areas overlapped so broadly that their bird populations are listed together in Table 2. Mimeographed maps were prepared from aerial photograps. Bird activity was recorded on these maps after the method of Williams (1936), Ken-

Table 2. Breeding bird populations; number of pairs per 100 acres, 40 hectares. (+ indicates bird found in area, but accurate breeding population not determined)

Species	Grassland and Forest-Edge	Forest Interior
Field sparrow *(Spizella pusilla)*	31	2
Lark sparrow *(Chondestes grammacus)*	24	
Rufous-sided towhee *(Pipilo erythrophthalmus)*	5	
Mourning dove *(Zenaidura macroura)*	4	
Brown thrasher *(Toxostoma rufum)*	3	
Cardinal *(Richmondena cardinalis)*	3	
Summer tanager *(Piranga rubra)*	2	
Grasshopper sparrow *(Ammondramus savannarum)*	2	
Mockingbird *(Mimus polyglottos)*	1	
Bluejay *(Cyanocitta cristata)*	+	+
Bobwhite *(Colinus virginianus)*		8
Tufted titmouse *(Parus bicolor)*		8
Black-capped chickadee *(Parus atricapillus)*		4
Nighthawk *(Chordeiles minor)*		2
Whip-poor-will *(Caprimulgus vociferus)*		2
Downy woodpecker *(Dendrocopus pubescens)*		2
Crested flycatcher *(Myiarchus crinitus)*		2
Number of species	10	9
Number of pairs	75	30

deigh (1944), and Enemar (1959). Sixteen complete surveys were made between 17 March and 7 July, 1968. A total of 72 census hours were spent in the field. Composite maps were prepared for each species and the number of pairs per 100 acres, 40 hectares, calculated.

Bird life was quite scanty in all census areas (Table 2). The largest number of species and pairs occurred in the grassland and on the forest-edge. The field and lark sparrows were the most conspicuous and predominant species. The lark and grasshopper sparrows are the only typically grassland species in this group. In contrast, Blem (1968) totaled 528 pairs of breeding birds per 100 acres, 40 hectares, in a deciduous forest along the Sangamon River near Mahomet, Illinois and Karr (1968) obtained populations of 329 to 489 pairs per 100 acres, 40 hectares, in shrub and forest vegetation in east-central Illinois. While the sand prairie and scrub forest areas have an abundance of such insect food as grasshoppers, the lack of water, thickets, and diversified vegetation appear to exclude many species.

The most distinctive bird species of this sandy habitat, the lark sparrow, has not generally been considered a common nesting species in Illinois (Johnson 1968). However, its restriction and prevalence in sandy areas over the state has been known for some time (Eifrig 1913, Vestal 1913). This is the first quantitative study of the species or of the bird population in general on this type of terrain in Illinois. Large numbers of blue jays occurred in the area and doubtlessly some nested. Sixteen birds were counted on 6 May but evidence is accumulating that many birds at this time of the year are daytime transients moving northward. Other species were seen occasionally during the summer but they nested off the area.

Summary

1. Sand prairie and scrub forest on the Wilkinson Farm, near Bath, Illinois, were studied in the spring and summer of 1968 with respect to composition and density of the vegetation and mammal and bird populations.

2. The dominant grasses are *Andropogon scoparius, A. furcatus, Stipa spartea, Koeleria cristata,* and *Panicum pseudopubescens.* The dominant trees are *Quercus marilandica* (61% total stems, 50% total basal area), *Q. velutina* (28%, 46%), and *Carya ovalis* (11%, 4%).

3. *P. leucopus* is the most numerous mammal species and is more abundant in the forest than on the prairie. *P. maniculatus* is more numerous than *Microtus ochrogaster,* and both species are largely restricted to the prairie. Mammals are more numerous than birds.

4. Maximum distances between recaptures of marked individual mammals, which may provide some indication of the size of home ranges, average 68 feet, 20.7 meters, for *Peromyscus leucopus* in the sand prairie and 128 feet, 39.5 meters, in the forest-interior and for *P. maniculatus* in the sand prairie, 146 feet, 45 meters.

5. Only 17 bird species were found nesting with populations of about 75 pairs per 100 acres, 40 hec-

tares, in the sand prairie and forest-edge and 30 pairs per 100 acres, 40 hectares, in the forest. The lark and field sparrows were the predominant species. These population densities are very low compared with other areas in central Illinois.

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DISTRIBUTION AND ABUNDANCE OF THE GRAY PARTRIDGE IN ILLINOIS

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ABSTRACT. — Through use of a rural letter carrier survey, hunter kill data, and a County Conservation Inspector survey the present distribution and relative abundance was determined for the Gray Partridge (*Perdix perdix*) in Illinois. Since 1943 the species has spread westward, southwestward, and southward in Illinois and is now distributed over the northern quarter of the state. The present area of highest relative abundance in the state, 5.9 birds observed in late August per 100 miles of roadside, is Lee County. The climate during summer for that part of Illinois having Gray Partridge may be too hot and wet to allow a high rate of reproduction and may keep partridge popuations relatively low.

The Gray Partridge was introduced into the United States as early as 1790 (Leopold, 1933), but most introductions were made during the late 1800's and early 1900's (Edminster, 1954). Within its native range of Europe and southwestern Asia the species is most abundant and common in central and southeastern Europe (Edminster, 1954).

During the period 1906 through 1927 over 12,000 Gray Partridge were released in Illinois by the state (Leopold, 1931). The locations of most of these releases are not known. The Gray Partridge now present in Illinois originated from these releases, local releases by private individuals or groups, population spread from releases made in southern Wisconsin, 1908 through 1929, or a combination of these.

Leopold (1931) for 1929 and McCabe and Hawkins (1946) for 1942 provide previous descriptions of the geographic range of the Gray Partridge in Illinois. Since 1943 there has been no description of the geographic range of the Gray Partridge in Illinois. This research was designed to determine the present distribution and relative abundance of the species in Illinois.

Acknowledgment is made to the following: to Drs. J. Henry Sather and John E. Warnock of Western Illinois University, for advice and counseling received and critical reading of the manuscript; to Mr. William Preno of the Illinois Department of Conservation, the United States Postal Authorities, the Illnois Rural Letter Carrier Association, and the County Conservation Inspectors of the Illinois Department of Conservation for aid in gathering the distribution and relative abundance data; to Mrs. Allen L. Farris for encouragement and critical reading of the manuscript.

METHODS

Surveys:

Three techniques were used to de-

termine the distribution of the Gray Partridge in Illinois: a rural letter carrier survey, hunter kill information, and a County Conservation Inspector questionnaire survey. The rural carrier census also provided data on relative abundance.

A summer rural letter carrier survey was conducted in 41 northern counties in Illinois from August 24 through 28, 1964. A form letter of instruction was sent to postmasters and rural letter carriers associated with the 458 post offices located in these 41 counties. To aid in the identification of the partridge, line drawings of a Gray Partridge and a Bob-White Quail (*Colinus virginianus*), along with a written description of each species, were included in the materials sent to the letter carriers.

Census cards returned by the postmen were analyzed using the method described by Greeley, Labisky, and Mann (1962). The number of birds observed and the number of miles driven during the five day census period in each township were used to calculate the number of partridge per 100 miles of roadside in each township. If the route of a mail carrier extended into two or more townships, the reported data were divided equally among all the townships listed on the questionnaire. The distribution and abundance of the Gray Partridge in Illinois were plotted on the basis of these calculations.

Rural letter carrier censuses have been used in several states as a technique for censusing various types of wild animals. Biases in the technique have been recognized (Greeley, *et. al.*, 1962); however, the data obtained are considered to be generally reliable and year to year fluctuations in distribution and relative abundance of various species of wildlife over wide geographical areas are detectable.

Hunter kill information was obtained from the Illinois Department of Conservation. This information was obtained by the department from a sampling of two percent of the resident hunting license holders in the state (Preno, personal communication).

The third censusing method employed questionnaires sent to County Conservation Inspectors, of the Illinois Department of Conservation, of 33 northern counties in Illinois in December, 1965. A letter of introduction and explanation was included with each questionnaire. The questionnaire was used to obtain the opinions of the inspectors with regard to distribution of the species in each county, species population trends in Illinois, and hunter utilization of the species in Illinois.

Climographic test of range:

Twomey (1936) used climographs to compare the climates of the native European range of the Gray Partridge with various American ranges to which the species had been introduced. To construct a "standard" climograph representing the European range, he superimposed on one another various local European climographs and then connected their extremities. The resulting figure is assumed to represent the range of temperature and precipitation for areas in which the Gray Partridge thrives. For comparison with the Illinois range, the Twomey polygon for the European optimum was

transposed on a series of Illinois climographs. Climographs for five different areas in Illinois are shown: Rockford airport, Dixon, Galesburg, Ottawa, and three miles south of Kankakee (Fig. 1). Temperature and precipitation data are presented as long term averages (1931-1960) from United States Weather Bureau data.

Results and Discussion

Surveys:

A total of 768 census cards were mailed to the rural letter carriers, and 560 or 72.9 percent were returned; 521 or 93 percent of the 560 cards returned were usable or 67.8 percent of all cards sent. This rural letter carrier survey indicated that the Gray Partridge was distributed over a continuous range including all or parts of 16 counties (Fig. 2 and Table 1). Four other counties were reported to contain isolated populations (Table 1). The highest concentration of 19.1 birds per 100 miles on a township basis was reported in Somonauk Township, DeKalb County, and Adams Township, LaSalle County. The lowest concentra-

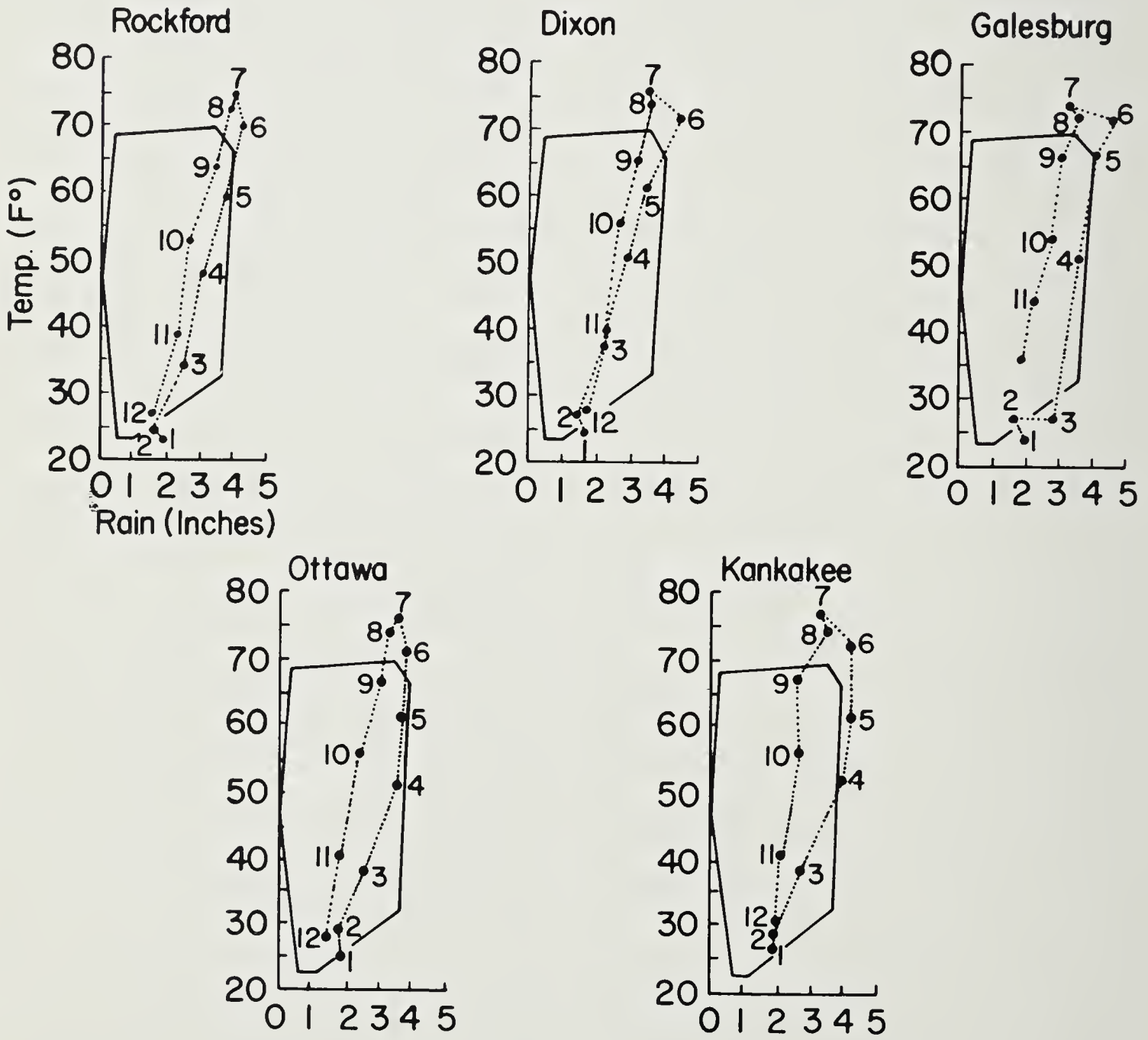

Figure 1. Climographs for five cities in northern Illinois (dotted lines) compared with the climograph for the optimum range for the Gray Partridge in Europe. Numbers indicate months, January through December. (Adapted from Twomey, 1936.)

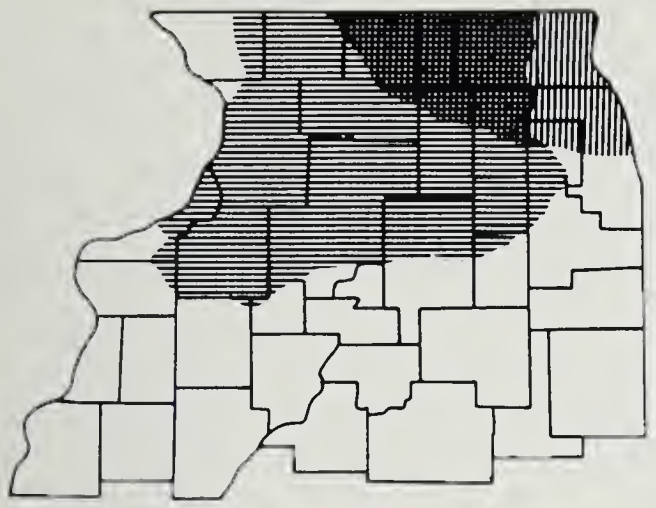

FIGURE 2. Distribution of the Gray Partridge in Illinois in 1943 (crossed and vertical lines) and 1966 (crossed and horizontal lines).

tion in the continuous range occured in Naperville Township, DuPage County, which was 0.1 birds per 100 miles. The population indices indicated by the rural letter carrier survey provide a basis for comparison of relative abundance among Illinois counties within the Gray Partridge range. The highest concentration of partridge on a county basis was reported from Lee County and the lowest concentration from Knox and Livingston Counties.

During August the development

TABLE 1. Gray Partridge relative abundance, hunter kill, and county distribution from County Conservation Inspector responses.

County	Average Number of Partridge Observed Per 100 Miles		Total Kill/Trip 1961-1965	County Inspector Response
	County[1]	Township[2]		
Lee	5.85	7.85	0.49	Yes
Ogle	3.27	4.59	1.33	Yes
DeKalb	2.98	3.78	0.93	Yes
Boone	2.80	2.80	0.46	Yes
Carroll	2.43	3.10	0.33	Yes
Kane	1.93	3.38	0.56	Yes
Kendall	1.45	3.38	P	Yes
Whiteside	1.40	2.30	0.34	Yes
Bureau	1.31	2.34	0.38	Yes
McHenry	1.31	2.81	0.51	Yes
Stephenson	1.22	2.08	P	Yes
LaSalle	0.76	4.70	P	Yes
Winnebago	0.76	1.53	0.95	NI
Henry	0.40	3.22	NR	Yes
Will[3]	0.20	1.63	P	Yes
Rock Island	0.12	0.75	P	Yes
JoDaviess	0.06	0.24	NR	Yes
DuPage	0.04	0.17	P	NI
Warren[3]	0.03	0.17	NR	No
Knox[3]	0.01	0.06	NR	NI
Livingston[3]	0.01	0.10	NR	No
Cook	NC	NC	P	NI
Grundy	NR	NR	NR	Yes
Lake	0.00	0.00	P	Yes-No[4]
Stark	NR	NR	NR	Yes

1. Values obtained by adding together the values for all townships within a county of Gray Partridge observed per 100 miles and dividing by the number of townships within a county. 2. Values obtained by adding together the values for all townships within a county of Gray Partridge observed per 100 miles and dividing by the number of townships reported to contain Gray Partridge in each county. 3. Isolated populations reported. 4. Two Conservation Inspectors reported for Lake County.

of the vegetation is extensive and restricts the field of vision of the observer. Greeley, *et al.* (1962) working with Ring-necked pheasants (*Phasianus colchicus*) in Illinois, state that during August, the number of pheasants observed by the rural letter carriers was below the number seen in the winter or spring, even though more pheasants were present in late summer than in winter or spring. The same situation probably exists for the partridge; therefore, from this information and my observations I believe that a spring and/or early summer census would have shown higher population indices in the state.

Hunter kill data, obtained for the 1961 through 1965 hunting seasons from Mr. William Preno of the Illinois Department of Conservation, aided in determining the current distribution of the Gray Partridge in Illinois. These data indicate 18 counties in which one or more partridge were killed in one or more of the years 1961 through 1965 (Table 1); no information concerning abundance is inferred.

Replies were received from 28 of the 33 County Conservation Inspectors contacted. Comparison of the rural letter carrier distribution data and the County Conservation Inspectors distribution data revealed close agreement except for the southern portions of the range. Information obtained from the inspectors may be more accurate if we assume that they are more familiar with the species and the county than would be the mail carriers.

Combining the distribution data obtained from the three surveys, a generalized distribution map of the Gray Partridge in Illinois was compiled (Fig. 2). Comparison of this map with that presented by McCabe and Hawkins (1946) shows that in the last 23 years the Gray Partridge has spread westward, southwestward, and southward in Illinois. The area of established populations now encompasses approximately the northern one fourth of the state.

Hunting pressure on the Gray Partridge in Illinois is light. County Conservation Inspectors report that most of the partridge are taken while hunting other upland game species, especially pheasants. Population trends, as indicated by information obtained from County Conservation Inspectors, seem to be upward; however, no long term population trends are available.

Climographic test of range:

The effects of climate on an introduced species play a vital role in the success of establishment and densities attained by that species in a new area. A technique used to evaluate the effects of climate on a species is the climograph (hythergraph) (Twomey, 1936).

McCabe and Hawkins (1946) used this technique for investigating the effects of climate on Gray Partridge distribution and abundance in Michigan, Ohio, and Wisconsin. They found that compared with the European optimum, climatic conditions protrude outside the optimum in Michigan, Ohio, and Wisconsin during the period in which the chicks are raised. These three states have established populations of Gray Partridge that are reportedly existing at low levels. From the data presented by McCabe and Hawkins (1946) it

appears that winter departures from the optimum conditions are tolerated; but, unless the summer climatic conditions, which affect the survival of the young, fall within the Twomey polygon, the species fails or does not thrive.

The climate of Illinois is similar to that described by McCabe and Hawkins (1946) for Michigan, Ohio, and Wisconsin. The climatic averages for Illinois for the period of chick rearing, June, July, and August, protrude outside the optimum conditions of the native range (Fig. 1). Dale (1942), working in Michigan, found that following a series of wet summers Gray Partridge populations were low, and following a series of dry summers partridge populations were relatively high. He states that in contrast to the pheasant, the Gray Partridge requires relatively dry weather during the hatching season for satisfactory reproduction.

These climographic data indicate that in summer, temperature (too high) and rainfall (too much) may well be limiting factors for the distribution and abundance of the Gray Partridge in Illinois. Illinois probably will retain partridge in relatively low densities. If this hypothesis is correct, their numbers can be expected to fluctuate in conjunction with variations in summer weather conditions; dry, cool summers should result in higher population levels than wet, hot summers.

Acknowledgments

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ON THE USE OF JACOBIAN ELLIPTIC FUNCTIONS TO GENERALIZE POTENTIAL ENERGY FUNCTIONS

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ABSTRACT. — It is shown that the potential functions used in molecular problems which contain an exponential factor or a hyperbolic function factor are special cases of a class of functions containing Jacobian elliptic functions. The behavior of the generalized function, using a specific potential function as an example, upon the parameter, m, is described. The sensitiveness of the generalized function to molecular parameters is also investigated.

The typical wave function in atomic and molecular wave mechanical problems contains a decreasing exponential factor (e.g. cf. Eyring, et. al., 1934, p. 89). As a consequence of this fact, many empirical and semiempirical potential energy functions which have been used to describe diatomic molecules, have also used an exponential factor. Using the Eulerian transformations (Dwight, 1947, p. 145), it is possible to express exponential functions in terms of hyperbolic functions. The hyperbolic functions are a limiting case of the Jacobian elliptic functions (Milne-Thomson, 1950). The conventional circular (trigonometric) functions are another limiting case of the Jacobian elliptic functions.

Circular functions are periodic in the real plane and hyperbolic functions are periodic in the complex plane. The more general elliptic functions are doubly periodic. This property would appear to make elliptic functions unsuitable in the construction of potential functions for diatomic molecules. On the other hand, it would appear of interest to investigate the relation of functions containing the specialized hyperbolic functions to the general elliptic functions and to the special circular functions. This investigation is the subject of this paper.

The investigation is made with the use of a semiempirical potential energy function, suggested by Frost and Musulin (1954) as an example. This function, in atomic units (Energy: 1 a.u. = 27.210 eV; Charge: 1 a.u. = 4.80286×10^{-10} e.s.u.; Mass: 1 a.u. = 9.1083×10^{-28} g; Length: 1 a.u. = 0.529172×10^{-8} cm.) is

$$V = e^{-aR}\left(\frac{1}{R} - b\right) \qquad (1)$$

where V is the potential energy with its zero corresponding to infinite separation, R is the internuclear distance, and a and b are constants to be determined for a given diatomic molecule or group of diatomic molecules.

GENERALIZATION OF THE POTENTIAL FUNCTION

A combination of the Eulerian relations permits the expression of the exponential and, therefore, equation (1) in terms of hyperbolic functions.

$$V = (\cosh aR - \sinh aR)\left(\frac{1}{R} - b\right) \qquad (2)$$

Then, with the aid of the usual relations between hyperbolic func-

tions, (2) can be recast.

$$V = \left(\frac{1}{\text{sech } aR} - \frac{\tanh aR}{\text{sech } aR}\right)\left(\frac{1}{R} - b\right) \qquad (3)$$

Elliptic functions depend upon a variable, u, and also a parameter, m. Tables of the functions, sn (u|m), cn (u|m), and dn (u|m), are available (Milne-Thomson, 1950). When the parameter, m, takes the value of 1.0, these elliptic functions become hyperbolic functions. The relations (Milne-Thomson, 1950) are

$$\text{sn } (u|1) = \tanh u$$
$$\text{cn } (u|1 = \text{dn } (u|1) = \text{sech } u \qquad (4)$$

The substitution of relations (4) into equation (3) lead to semiempirical functions written in terms of Jacobian elliptic functions. The plural is used because two of the elliptic functions have the same hyperbolic limit. The various permutations of the elliptic functions then gives rise to four, different, possible potential energy functions. The four possibilities are

$$V = \left[\frac{1}{\text{cn } (aR|1)} - \frac{\text{sn } (aR|1)}{\text{cn } (aR|1)}\right]\left[\frac{1}{R} - b\right]$$
$$V = \left[\frac{1}{\text{dn } (aR|1)} - \frac{\text{sn } (aR|1)}{\text{dn } (aR|1)}\right]\left[\frac{1}{R} - b\right] \qquad (5)$$
$$V = \left[\frac{1}{\text{cn } (aR|1)} - \frac{\text{sn } (aR|1)}{\text{dn } (aR|1)}\right]\left[\frac{1}{R} - b\right]$$
$$V = \left[\frac{1}{\text{dn } (aR|1)} - \frac{\text{sn } (aR|1)}{\text{cn } (aR|1)}\right]\left[\frac{1}{R} - b\right]$$

The quotients and reciprocals may be changed, with the use of the usual relations between elliptic functions, into other elliptic functions which allow the above relations to be written in a more simple form. The generalization of a potential energy function, written in terms of hyperbolic functions, follows from equations (5). In these equations, elliptic functions with a parametric value of 1 are used. A more general expression is obtained if one allows the elliptic functions their usual dependence upon the parameter, m. The generalized equations, after re-expressing the quotients and reciprocals, are

$$V = \left[\text{nc } (aR|m) - \text{sc } (aR|m)\right]\left[\frac{1}{R} - b\right] \qquad (6)$$
$$V = \left[\text{nd } (aR|m) - \text{sd } (aR|m)\right]\left[\frac{1}{R} - b\right] \qquad (7)$$
$$V = \left[\text{nc } (aR|m) - \text{sd } (aR|m)\right]\left[\frac{1}{R} - b\right] \qquad (8)$$
$$V = \left[\text{nd } (aR|m) - \text{sc } (aR|m)\right]\left[\frac{1}{R} - b\right] \qquad (9)$$

Variation of the Parameter

The generalized equations (6) through (9) are tested using the hydrogen molecule, H_2, as an example. The values of a and b are taken from Frost and Musulin (1954). The values of the various elliptic functions are obtained directly for several values of m between 1 and 0, including these limiting cases, from the tables of Milne-Thomson (1950). Values of the elliptic functions were also obtained for two negative values of m and for two values of m greater than 1. These values of the functions were obtained by first using the Jacobi transformations to change the function with a parameter whose value is outside the range $0 \leq m \leq 1$ to a function with a parameter whose value is inside the range $0 \leq m \leq 1$.

The parametric family of curves for equations (6) through (9) are given in Figures 1 through 4, respectively. It is to be noted that, on each figure, the curve for m=0 corresponds to a modified circular function. The modified circular functions corresponding to equations (6) through (9) are (in the same tabular order)

$$V = (\sec aR - \tan aR) \quad (\frac{1}{R} - b) \tag{10}$$

$$V = (1 - \sin aR) \quad (\frac{1}{R} - b) \tag{11}$$

$$V = (\sec aR - \sin aR) \quad (\frac{1}{R} - b) \tag{12}$$

$$V = (1 - \tan aR) \quad (\frac{1}{R} - b) \tag{13}$$

It should be noted that the limits expressed in equations (12) and (13) indicate that the generalizations (8) and (9) are doubly deficient in the requirements of a good potential energy function. Not only are equations (8) and (9), like (6) and (7), periodic in the real plane, but they are also singular at points in the real plane other than R=0 and R=∞. These singularities result from the fact that cn (aR|m) is periodically zero while dn (aR|m) is not. In equation (6) the resulting infinities cancel, but no such cancellation can occur in equations (8) and (9).

Variation of Molecular Constants

Although Figures 1 through 4 clearly indicate the behavior of the generalized potential energy function with a variation of the parameter m, it seemed appropriate to complete the study by testing the sensitivity of the generalized function to the molecular constants, a and b. Figure 5 shows the parametric curves for selected values of m between 1 and 0 for the hydrogen molecular ion, H_2^+.

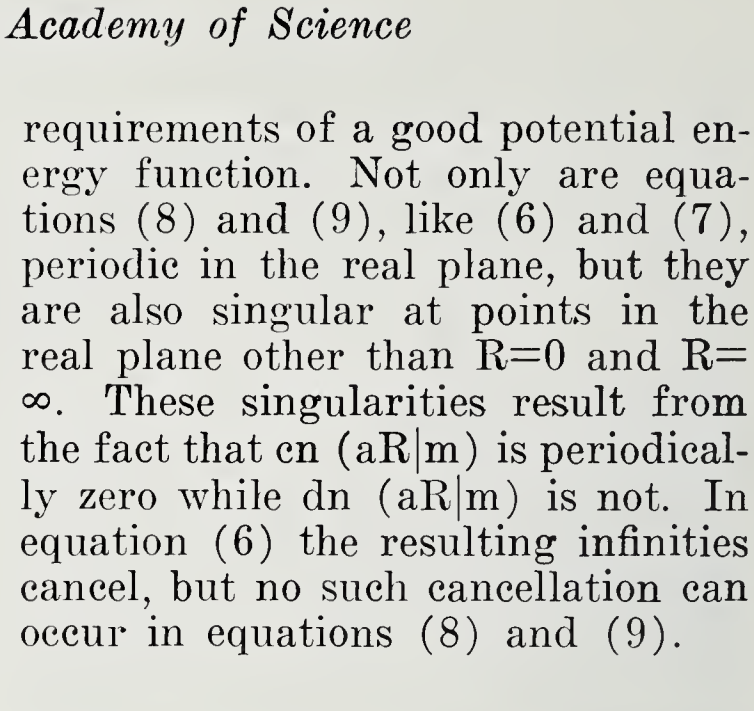

FIGURE 1.—$V = \left[nc\,(aR|m) - sc\,(aR|m) \right] \left[\frac{1}{R} - b \right]$ for H_2

(Each curve is labeled by the parametric value of m)

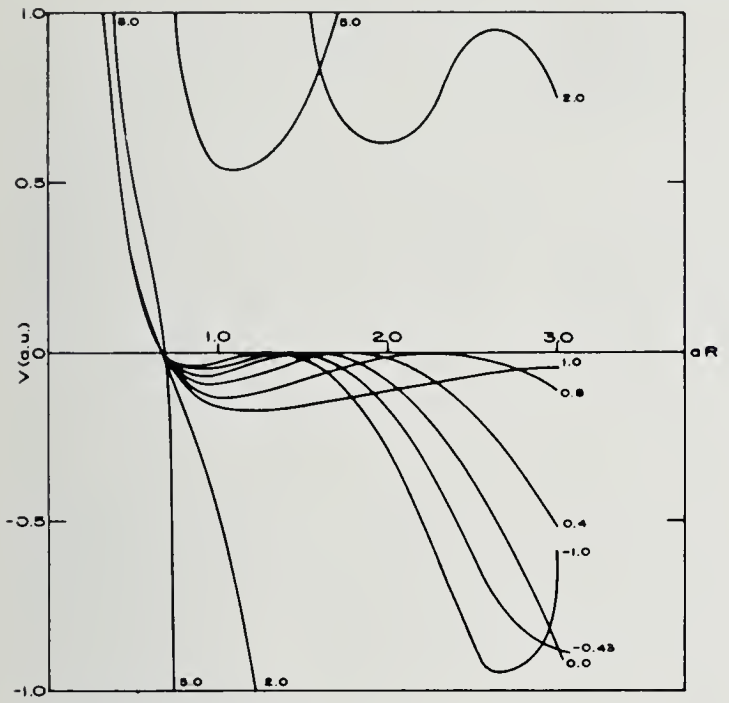

FIGURE 2.—V =

$$\left[\text{nd}\,(aR|m) - \text{sd}\,(aR|m)\right]\left[\frac{1}{R} - b\right] \text{ for } H_2$$

(Each curve is labeled by the parametric value of m)

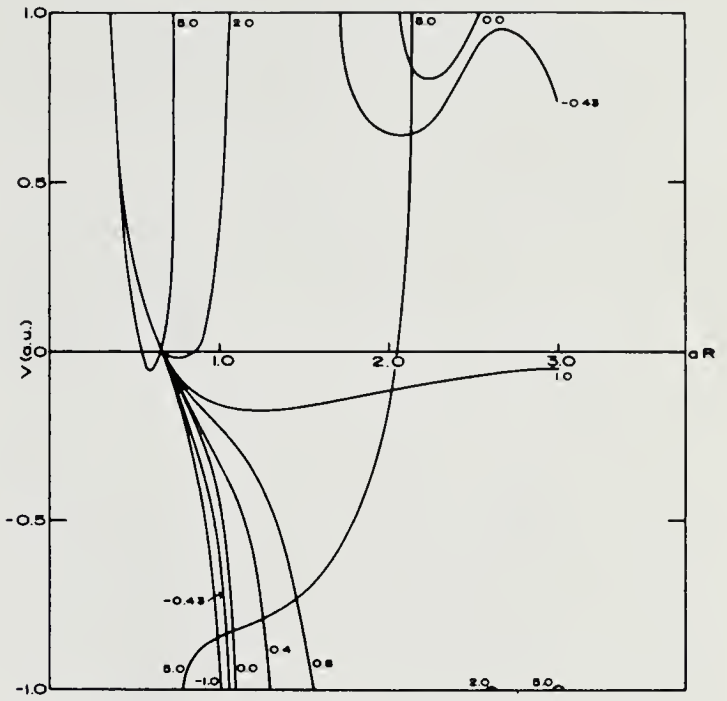

FIGURE 3.—V =

$$\left[\text{nc}\,(aR|m) - \text{sd}\,(aR|m)\right]\left[\frac{1}{R} - b\right] \text{ for } H_2$$

(Each curve is labeled by the parametric value of m)

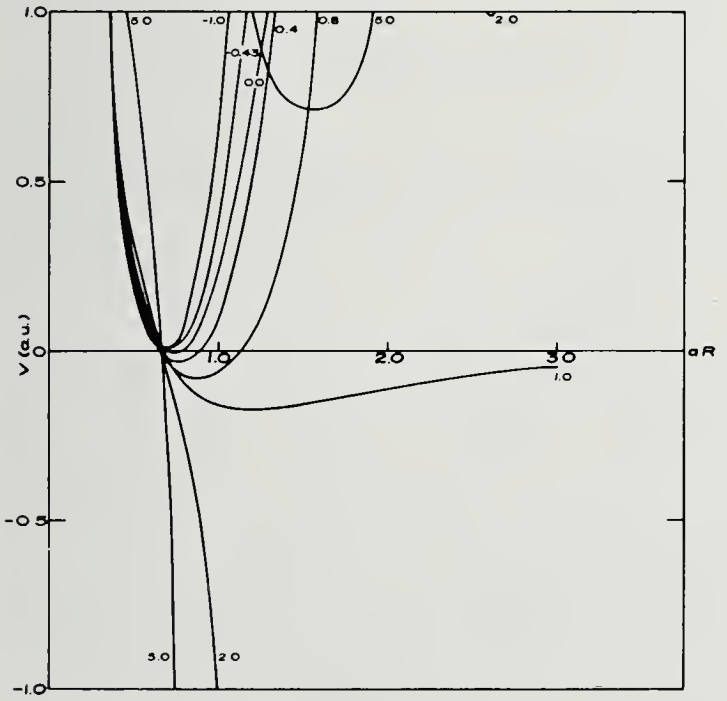

FIGURE 4.—V =

$$\left[\text{nd}\,(aR|m) - \text{sc}\,(aR|m)\right]\left[\frac{1}{R} - b\right] \text{ for } H_2$$

(Each curve is labeled by the parametric value of m)

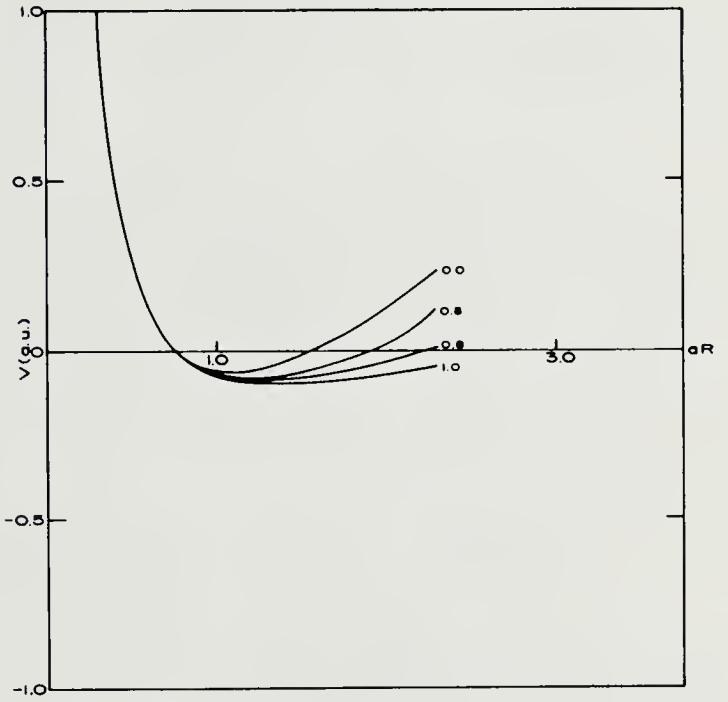

FIGURE 5.—V =

$$\left[\text{nd}\,(aR|m) - \text{sc}\,(aR|m)\right]\left[\frac{1}{R} - b\right] \text{ for } H_2^+$$

(Each curve is labeled by the parametric value of m)

Discussion

A study of Figures 1 through 5 indicates that the use of Jacobian elliptic functions allows one to show that the usual empirical and semi-empirical potential energy functions

(and the approximate wave-mechanical solutions for molecular problems, as well) are but one member of a general parametric family of curves. It is well known that the usual postulates of quantum mechanics (Eyring, et. al. 1934) restrict the acceptable solutions and consequently, the forms of the solutions of the eigenvalues. However, the fact becomes almost startling by examining Figures 1 through 5 where the behavior of the potential function for m=1 is completely different from all other members of the family. Of course, if these curves had been drawn in the complex plane instead of the real plane, the same statement would be true for the function with m=0.

Not only do the postulates of quantum mechanics limit the form of the acceptable solutions, but the very nature of the differential equation also dictates the form of the solutions. Morse and Feshbach (1953, Ch. 6) have shown that the signs of the coefficients in the differential equation determine whether hyperbolic or circular solutions are obtained from the Sturm-Liouville problem. The present investigation indicates that there is a smooth transition between these two limiting cases.

All members of the parametric curves have similar behavior for small values of R. This fact could have been predicted from a consideration of the series expansions of the various functions and their limiting values.

Any zeros in the potential function which are not due to the exponential factor must also appear in the general function. In this example, all curves pass through R=l/b. Thus, the generalized function behaves properly in regions of small R and is also fitted at certain values of R.

It should also be noted that the first minimum (where this is appropriate) is always at a more positive value of V than that obtained with the curve whose parametric value of m is 1. This is another instance where the inclusion of an additional parameter does not improve the potential function. Musulin (1959) has shown that it is not always possible to improve empirical and semiempirical functions by the inclusion of additional parameters. In this case the reason is apparent because of the above mentioned considerations of restrictions placed upon quantum mechanical solutions.

The generalized equation exhibits the same sensitiveness to molecular parameters as the usual potential function containing an exponential factor.

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ASYMPTOMIC SOLUTIONS OF THE BORN-OPPENHEIMER NUCLEAR EQUATION WITH THE FROST-MUSULIN POTENTIAL FUNCTION

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Abstract. — The asymptotic soutions of the Born-Oppenheimer equation for a particular semi-empirical potential are discussed. Some mathematical equations and functions are used, for the first time, in a chemical problem. A formal demonstration is given of the common notion that a molecule is a perturbed atom.

In the Born-Oppenheimer approximation, (Slater, 1963) the equation for the nuclear motion of a diatomic molecule is

$$\left[-\frac{1}{2M_1}\nabla_1^2-\frac{1}{2M_2}\nabla_2^2+E(X_1,\ Y_1,\ Z_1,\ X_2,\ Y_2,\ Z_2)\right]$$
$$v((X_1,\ Y_1,\ Z_1,\ X_2,\ Y_2,\ Z_2)$$
$$=\mathcal{E}v(X_1,\ Y_1,\ Z_1,X_2,\ Y_2,\ Z_2) \qquad (1)$$

where the M_i are the masses of the nuclei, ∇_i^2 are the Laplacian operators representing the kinetic energy operators of the nuclei, $E(X_i, Y_i, Z_i)$ is the energy solution of the Schrödinger equation for fixed nuclei which serves as the potential energy function in Equation (1), $v(X_i, Y_i, Z_i)$ is the wave function, and $\mathcal{E}$ is the approximate eigenvalue to the exact Schrödinger equation. Equation (1) is stated in atomic units. (Energy: 1 hartree = 27.210 eV; Mass: 1 a.u. = 9.1083×10^{-28}g; Length: 1 bohr = 0.52917×10^{-8} cm; Charge: 1 a.u. = 4.80286×10^{-10} e.s.u.)

After the usual change of coordinates, the separation of angular wave functions, and the introduction of the radial probability function, P(r), where

$$P(r) = rR(r) \qquad (2)$$

the following differential equation for the function P(r) is obtained.

$$\frac{d^2P}{dr^2}+2\mu\left[\mathcal{E}-E(r)-\frac{A}{2\mu r^2}\right]P=0 \qquad (3)$$

where R(r) is the radial portion of $v(X_i, Y_i, Z_i)$, E(r) is that portion of the potential energy function which is independent of angles, A is a separation constant, and μ is the reduced mass (Eyring, et al., 1944). If the constant A is set to zero, the equation for the lowest rotational state is obtained.

$$\frac{d^2P}{dr^2}+2\mu\ [\mathcal{E}-E(r)]\ P=0 \qquad (4)$$

One may reintroduce the rotational problem by considering the term containing A as a perturbation to Equation (4). The purpose of this note is to investigate the solutions to Equation (4) if E(r) is given by the semiempirical potential energy function suggested by Frost and Musulin (1954). Substitution

of their E(r) into Equation (4) yields

$$\frac{d^2P}{dr^2} + 2\mu\left[\mathcal{E} - e^{-ar}\left(\frac{1}{r} - b\right)\right] P = 0 \qquad (5)$$

where a and b are constants, order of magnitude of 1 and minimum order of magnitude of 1, respectively.

Large r

For very large values of the internuclear distance, the potential energy terms of Equation (4) vanish. The asymptotic solutions correspond to those of a free wave ($\mathcal{E} > 0$) or an exponential function ($\mathcal{E} < 0$).

For molecules with moderately large values of b, at least $0(10^2)$, and with values of the internuclear distance such that $1/r$ becomes negligible compared to b, Equation (5) becomes

$$\frac{d^2P}{dr^2} + 2\mu\left[\mathcal{E} + be^{-ar}\right] P = 0 \qquad (6)$$

The substitutions

$$\gamma^2 = \frac{-8\mu\mathcal{E}}{a^2} \qquad z = \frac{2\ (2\mu b)^{1/2}}{a}\ e^{-ar/2}$$

transform Equation (6) into

$$z^2\ \frac{d^2P}{dz^2} + z\ \frac{dP}{dz} + (z^2 - \gamma^2)\ P = 0 \qquad (7)$$

which is the standard form of the differential equation whose general solution for $\mathcal{E} < 0$ is

$$P = c_1 J\gamma\ (z) + c_2 Y\gamma\ (z) \qquad (8)$$

where $J\gamma(z)$ and $Y\gamma(z)$ are Bessel functions of the first kind and of the second kind, respectively, and c_1 and c_2 are arbitrary constants (Abramovitz and Stegun, 1964). The constant c_2 must be taken as zero since $Y\gamma(z)$ is unbounded as z approaches zero, i.e., as r approaches infinity.

For $\mathcal{E} > 0$, the asymptotic solutions are Bessel functions of imaginary order whose series solutions are known (Watson, 1944). Mathematically, the results are consistent with the results which one obtains at infinite internuclear distances where the potential function vanishes.

Small r

For small values of the internuclear distance, the exponential of the potential function may be expanded about zero; whence, retaining terms through order of r^0, one obtains

$$\frac{d^2P}{dr^2} + \left\{2\mu\left[\mathcal{E} - \frac{1}{r} + (a + b)\right]\right\} P = 0 \qquad (9)$$

If one lets

$$2\mu\left[\mathcal{E} + (a + b)\right] = -s^2$$

Equation (8) becomes

$$\frac{d^2P}{dr^2} - \left[s^2 + \frac{2\mu}{r}\right] P = 0 \qquad (10)$$

which is an example of the Hamburger equation of the second order (Ince, 1944).

The necessary condition that Equation (10) have a normal solution is

$$\mathcal{E} = -\frac{\mu}{2n^2} - (a + b) \qquad (11)$$

where n is a positive integer. Alternatively, the same condition can be obtained by requiring proper be-

havior of the solution found by the method of undetermined coefficients. That is, Equation (11) is the condition for obtaining a set of polynomials as solutions to Equation (9).

The probability function obtained from Equation (10) is a Bateman function (Bateman, 1931). Like the Bessel function it is a special case of a confluent hypergeometric function.

The condition given in Equation (11) provides an interesting physical picture of molecular formation. The quantity $-(a+b)$ is the "united" atom energy, V_e^o, whereas the first term in Equation (11) is simply the energy of a hydrogen-like atom. Thus, for very small internuclear distances, a diatomic molecule behaves like an atom with a zero of energy equal to V_e^o. This physical behavior provides verification of the intuitive concept that a molecule, at small distances, is a perturbed atom.

Since V_e^o corresponds to the leading term of the expansion given by Brown and Steiner (1966), Equation (11) generalizes the information concerning the molecular electronic energy near the united atom to information concerning the total molecular energy near the united atom.

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A PREHISTORIC ARCHAEOLOGICAL RECORD OF THE ROSEATE SPOONBILL IN ILLINOIS

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ABSTRACT. — The skeleton of an adult roseate spoonbill, *Ajaia ajaia,* was found in a Hopewellian burial tomb in Gibson Mound 3, Calhoun County, Illinois. Numerous mortuary pots from Hopewellian-period sites in the South and upper Midwest exhibit the spoonbill motif, and it is suggested that the roseate spoonbill may have been the model for this design. Internment of a complete bird in a tomb, one that was apparently given equal attention in the burial procedure as the human dead, is a unique trait for Illinois Hopewell.

During the summer of 1969, the Thomas Gilcrease Institute, Tulsa, Oklahoma, the Department of Anthropology, University of Chicago, and the Department of Anthropology, Indiana University, Bloomington, jointly sponsored excavation of the Gibson Mound Group, Calhoun County, Illinois. This group consisted of a series of seven Hopewellian burial mounds that had been built probably during the period of about A. D. 150-250. These mounds contained from several to as many as 50 human burials (Mound 2); they were situated on the west bluff of the Illinois River approximately one fourth mile south of Kampsville. About 30 years ago Lester Gibson of Alton, Illinois, excavated portions of several of the mounds and, long before this, other Indian relic collectors had disturbed some of the burials in search of artifacts.

Mound 3 was oval in shape, measuring approximately 35 by 47 feet, and did not exceed three feet in height above the natural ground level. A total of 28 human burials were recovered from the mound; most were extended, some parallel with the bluff. Near the center of the mound, a tomb in the form of a rectangular 18-inch-deep subfloor pit (about five by eight feet) had been first dug into the natural knoll that formed the base of the mound. At least a one-log-high crib had been placed around the edge of the pit; green clay was used as chinking between the logs and the ground. Small limestone slabs had been placed on the roof logs, which originally were positioned lengthwise with the tomb, as an added cover. The only pot found in Mound 3 occurred with a peripheral burial (Burial 28) and was a limestone tempered, four-lobed Baehr Zoned Rocker-Dentate Stamped type. The rocker stamping was quite large, indicative of a late classic vessel; in all probability the pot equates in time with the tomb occupants.

The factor which made this particular burial tomb unique was that, in addition to the adult male (over 50 years) and child (ca. 5 years) burials, the body of a roseate spoonbill (*Ajaia ajaia*) had been interred with the humans (Fig. 1). The skull of this adult bird was missing; since

FIGURE 1. Interior of Gibson Mound 3 burial tomb showing the roseate spoonbill skeleton *in situ* at the right.

there was no evidence of prior human disturbance or burrowing activity by rodents, it can only be assumed the head was removed before the bird was placed in the tomb. The adult, child and bird were approximately one foot apart, and part of a cut mica figure lay at the feet of the bird.

This find is of both ornithological and archaeological significance. Relative to the spoonbill's present distribution in Illinois, Smith and Parmalee (1955) record it as "Accidental" and list what appears to be the last authenticated record for the state—a specimen collected in Adams County, April, 1887. Ridgway (1895) states that "Although, like the Carolina Parrakeet and Ivory-billed Woodpecker, the Roseate Spoonbill may not now be found in Illinois, I was informed, in 1879, by a taxidermist [Alexander Wolle, Sr., Baltimore, Md.] whom I have every reason to believe reliable, that some twenty years previously, or about 1859, he shot several specimens about some ponds in the Mississippi Bottoms below St. Louis." Cory (1909) mentions that " . . . it was apparently not uncommon fifty years ago in the southern part of the state." Kampsville is approximately 50 miles NNW of St. Louis; it is reasonable to assume that the bird in the Mound 3 tomb was taken locally, probably an individual that wandered north along the Illinois River. No remains of the spoonbill were found in the large faunal samples recovered at the Cahokia Site (St. Louis-E. St. Louis area; Parmalee 1957), even though occupants of this huge Middle Mississippian (ca. A. D. 900-1500) village and mound complex had made extensive use of the local bird fauna. Bones of this wader, a bird which today occurs locally along the Gulf Coast and in southern Florida, have not been reported thus far from any other archaeological sites in Illinois.

The fact that a complete or whole bird (minus the head) was considered significant enough by the Indians to award it the same treatment as that of human dead in the burial procedure is indeed unusual. Lower legs and/or claws, wings, and skulls and/or bills of birds were often used by prehistoric Midwestern Indian groups for decoration or in ceremonies (Parmalee 1958), and occasionally such parts were placed with the dead as grave offerings. The roseate spoonbill from Mound 3 may have represented simply a thing of beauty to the Indian, or a ceremonial object or hunting trophy, but one can only speculate on the reason for inclusion of a bird in the tomb. However, conceivably it was recognized as the model or form used widely as a decorative motif on pottery vessels.

Decorative spoonbill-like bird motifs have been widely used on pottery vessels throughout the "Hopewellian Interaction Sphere" as defined by Caldwell and Hall (1964). The illustrations in Fig. 2 were reproduced from W. H. Holmes (*Aboriginal Pottery of the Eastern United States.* 20th Ann. Report, 1903, Bur. Amer. Ethnol., p. 194); this particular pot was found in an Illinois mound by Dr. H. F. Snyder, probably at the Baehr Site (Brown County), and typifies the generalized bird form. Although conventionalized or stylized, the flared mandible and long

FIGURE 2. Stylized spoonbill motif design characteristic of many Hopewell-period mortuary pots.

neck have led archaeologists to refer to this particular pattern as the "spoonbill motif."

Ford and Willey (1940) illustrate several pots from the Crooks Site, LaSalle Parish, Louisiana, that depict this same bird motif; they state that "The most common decoration motif features the bird figure characteristic of the ceramics of the period. The head can usually be identified . . . ." Jennings in (Griffin 1952a), in referring to the Marksville pottery types recognized from the Crooks Site, mentions that "The raptorial or spoon bill bird is the most commonly used figure."

Specific identification of the "spoonbill" so prevalent as a design on Hopewellian-period pottery vessels, especially on those of lower Mississippi Valley groups, is questionable. Some writers, e.g. Griffin (1952a,b) refer to the motif as "spoonbill duck" (shoveler?). Earlier, Griffin (1941) had been more specific when describing an Illinois Hopewell Zoned incised vessel: "On the body, which is very slightly four lobed, there are three flying 'spoonbill' duck designs. These ducks are highly conventionalized." In any case, this bird motif appears primarily on mortuary pots; the occurrence of these identical bird designs on vessels from contemporaneous sites in several southern states and in the upper Midwest represents at least one trait that suggests certain cultural affinities. The reason or reasons why the Indians chose the roseate spoonbill for inclusion in the burial tomb will never be definitely established, but the fact that a bird, one which was probably uncommon to rare locally, was awarded the same burial rites as those of the humans merits special note.

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SYNTHESIS OF QUATERNARY AMMONIUM DIBASIC ACIDS, ANHYDRIDES AND ESTERS OF MORPHOLINE PIPERIDINE AND DIETHYLAMINE

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Abstract. — Several new organic dibasic acids, anhydrides and esters of morpholine, piperidine and diethylamine have been synthesized and characterized. Their molecular weights were determined potentiometrically with a silver, silver bromide indicating electrode versus a glass reference electrode. Morpholine, piperidine and diethylamine were dialkylated with ethyl bromacetate to form respectively, *N*,*N*-dicarbethoxymethylmorpholinium bromide (I) *N*,*N*-dicarbethoxymethylpiperidinium bromide (II) and diethyldicarbethoxylammonium bromide (III). These esters were hydrolyzed with concentrated hydrobromic acid to produce the dibasic acids, *N*,*N*-dicarboxymethylmorpholium bromide (IV), *N*,*N*-dicarboxymethylpiperidinium bromide (V) and dicarboxymethyldiethylammonium bromide (VIII), respectively. Compounds IV and V were successfully converted to their cyclic anhydrides, but compound VIII failed to produce the cyclic anhydride.

Morpholine, piperidine and diethylamine were successfully dialkylated with ethyl bromacetate to form *N*, *N*-dicarbethoxymethylmorpholinium bromide (I), *N*,*N*-dicarbethoxymethylpiperidinium bromide (II) and diethyldicarbethoxymethylammonium bromide (III). Hydrolysis of these esters with refluxing concentrated hydrobromic acid produced the corresponding dibasic acids. This method of synthesizing the dibasic acids proves to be a much more facile method than alkylating the secondary amines directly with bromoacetic acid. The monoacids are difficult to isolate and purify as shown by Remizov and Khromov-Bousov (1953).

N, *N*-dicarboxymethylmorpholinium bromide (IV) and *N*,*N*-dicarboxymethylpiperidinium bromide (V) were easily converted to their cyclic anhydrides (compounds VI and VII) by heating the dibasic acids below 90° in acetic anhydride.

Dicarboxymethyldiethylammonium bromide (VIII) could not be converted to the cyclic anhydride with acetic anhydride. Several other anhydride syntheses were attempted with similar results.

Materials and Methods

Apparatus — The potentiometric titrations were run using a Leeds and Northrup Model 7401 pH meter, a Beckman glass reference electrode (No. 41263) and a laboratory constructed silver, silver bromide indicating electrode. The indicating electrode was constructed from a No. 14 gauge silver wire and coated with silver bromide by immersing the wire as an anode in a 37% hydrobromic acid solution with a platinum wire as the cathode. The silver bromide coating was formed in 30 seconds at 0.5 volt.

Monoester Preparation—The monoesters of morpholine, piperidine and diethylamine were prepared by reacting the corresponding amine with ethyl bromacetate in a two to

one ratio in ethyl acetate. The excess amine was required to remove the hydrogen bromide liberated. Without an excess of secondary amine, the monoester yield was consideraly reduced. The per cent yields (based upon the secondary amine hydrobromide salt) and the boiling points were:

ethyl 4-morpholine acetate (IX), 99% yield, 68± 4° at 0.600 mm
ethyl 1-piperidine acetate (X), 95% yield, b.p. 56± 2° at 0.150 mm
ethyl *N*,*N*-diethylglycinate (XI), 95% yield, b.p. 50± at 2° at 3.50 mm

Dister Preparation—The diesters (I, II, III) were prepared by alkylating the monoesters (IX, X, XI) with ethyl bromacetate in refluxing ethyl acetate. The morpholine (46% yield) and piperidine (64% yield) diesters (I & II) precipitated as a solid, but the diethylamine diester (III) formed as an insoluble viscous liquid. Several attempts to recrystallize III from chloroform, ethyl acetate, methoxyethanol, ethanol, benzene and mixed solvents of these proved fruitless.

Diester I and II were recrystallized from a mixed solvent of ethyl acetate and absolute ethanol. Compounds I and II were not hygroscopic and had mp of 157-58° and 131.5-32.5° respectively.

Diester I; Anal. Calcd. for $C_{12}H_{22}O_5NBr$: C, 42.36; H, 6.52; N, 4.12; Br, 23.49. Found: C, 42.42; H, 6.32; N, 3.97; Br, 23.30. *Mol. Wt.* Calcd. 340.22. Found: 341 ± 2.

Diester II; Anal. Calcd. for $C_{12}H_{22}NBr$: C, 46.16; H, 7.15; N, 4.14. Found: C, 46.07; H, 7.16; N, 4.18. *Mol. Wt.* Calcd. 338.24. Found: 339 ± 1.

Diacid Preparations—The diacids (IV, V, VIII) were prepared by refluxing the respective diesters (I, II, and III) in an excess of 48% hydrobromic acid for 3 hours. The solvent was removed by a rotary evaporator.

Diacid IV was recrystallized from acetic acid containing 4% water; mp 193°d and 40% yield. Diacid V and VIII were recrystallized from acetic acid containing 5% acetic anhydride: V, mp 174°d, 43% yield; VIII mp 192°d, 39% yield. (The yield of VIII was based on the monester (XI) since the diester III could not be recrystallized).

Diacid IV; Anal. Calcd. for $C_8H_{14}O_5NBr$: C, 33.82; H, 4.95; N, 4.93. Found: C, 33.75; H, 4.95; N, 5.00. *Mol. Wt.* Calcd. 284.1. Found: 285 ± 1.

Diacid V; Anal. Calcd. for $C_9H_{16}0_4NBr$: C, 38.31; H, 5.72; N, 4.96; Br, 28.32. Found: C, 38.37: H, 6.20; N, 4.94; Br, 28.32. *Mol. Wt.* Calcd. 282.1. Found: 284 ± 1.

Diacid VIII; Anal. Calcd. for $C_8H_{16}O_4NBr$: C, 35.57; H, 5.97; N, 5.19; Br, 29:58. Found: C, 35.56; H 5.42; N, 5.19; Br, 29.63. *Mol. Wt.* Calcd. 270. Found: 271 ± 1.

As similar to the diester (I and II), the diacids (IV and V) were not hygroscopic.

Anhydride Preparations—The anhydrides VI and VII were prepared by heating the diacids in an excess of acetic anhydride at 80-90° for 3 hours. If the temperature was allowed to increase above 90°, degradation of the reactants occurred. Approximately one third of the solvent was distilled under aspirator pres-

sure to verify the formation of acetic acid. The anhydride crystals were insoluble in acetic anhydride, consequently, they were easily isolated. After washing with ethyl ether, the anhydrides were recrystallized from acetic acid containing 5% acetic anhydride. Anhydride VI was synthesized and recrystallized in a 41.-5% yield; mp 190-192°d, while anhydride VII was produced in a 56.-5% yield; mp 185.5°d.

Anhydride VI; Anal. Calcd. for $C_8H_{12}O_4NBr$: C, 36.12; H, 4.51; N, 5.26. Found: C, 32.62; H, 5.61; N, 5.32. *Mol. wt.* Calcd. 266; Found: 267.2 ± 0.1.

All molecular weights are given as averages and ranges of three determinations. The exception to this was diester I which is based on two duplicate determinations.

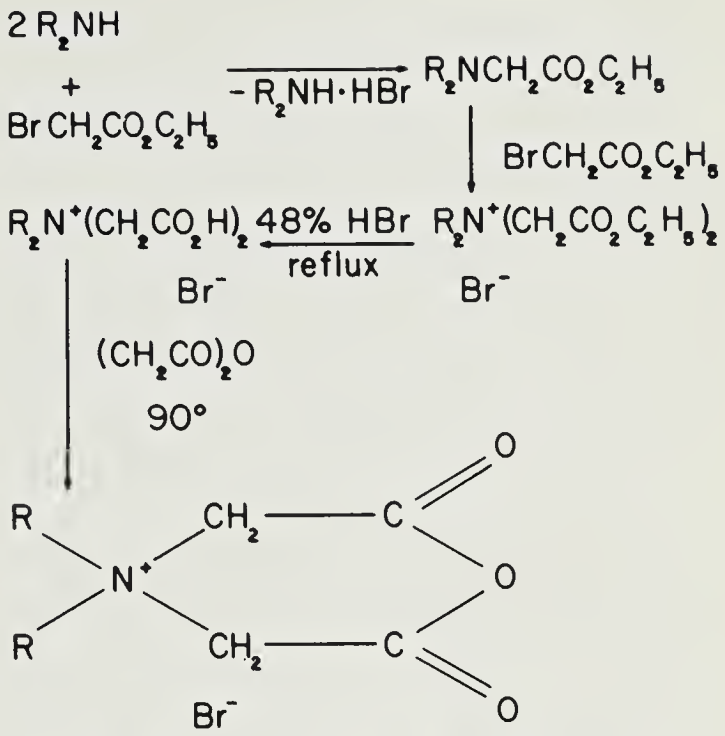

FIGURE 1. Synthesis of Quaternary Ammonium Dibasic Acids and Cyclic Anhydrides.

Discussions and Results

The conversion of secondary amines to quaternary ammonium salts is a well established reaction and several kinetic studies have been published by Grimm (1931), Laidler (1938) and Coleman (1955). This laboratory studied the conversion of secondary amines to quaternary ammonium dibasic acids via the hydrolysis of the dibasic esters. Subsequent research involved the conversion of these dibasic acids to cyclic quaternary ammonium anhydrides as outlined in Figure 1.

The anhydrides of morpholine and piperidine (VI and VII) were successfully synthesized, however, the anhydride of diethylamine was not formed by heating (80° - 90°) the corresponding diacid with acetic anhydride. Only unreacted starting material was recovered. If the acetic anhydride reaction was heated above 90°C, degradation of the diacid (VIII) occurred. Degradation at temperatures above 90° was observed, also, for the diacid of morpholine and piperidine (VI and VII).

Three additional anhydride syntheses were unsuccessful with diacid VIII. The benzenesulfonyl chloride-pyridine synthesis for anhydrides by Brewster (1955) resulted in rapid degradation of the starting material at the beginning of the reaction with no external source of heat added.

In the phosgene anhydride synthesis by Rinderknecht (1964), diacid VIII was converted successfully to the triethylamine salt. However, when the cold phosgene (12% in benzene) solution was added to this salt, triethylamine hydrochloride and starting material were recovered. The variation of the reaction temperature from the recommended ice-bath temperature to room temper-

ature failed to alter the course of the reaction.

Ethoxyacetylene reacts with acids in methylene chloride to form anhydrides and ethyl acetate according to a procedure by Eglenton (1954). Unfortunately, diacid VIII was not soluble in refluxing methylene chloride. Consequently, when a solution of ethoxyacetylene in methylene chloride was refluxed with diacid VIII, no reaction occurred.. The unreactivity of diacid VIII compared with the facile anhydride formation of diacids IV and V was indeed surprising to observe, especially so when Bruice (1965) had synthesized ten different 3,3-substituted glutaric anhydrides. The substituents of Bruice's anhydrides were combination of methyl, ethyl, *n*-propyl, isopropyl, *t*-butyl and phenyl. Bruice synthesized the anhydrides from the corresponding dibasic acids by heating the acids at reflux (120° - 160°) with acetic anhydride for at least 2 hours.

Earlier anhydride syntheses from substituted glutaric acids were made by Howles (1900). Howles discovered that *cis*-1-methyl-2-isopropylglutaric acid formed the anhydride if heated with acetyl chloride, but the *trans*-2-methyl-3-isopropyglutaric acid did not. It is worth noting that Bruice was successful in synthesizing both the 3,3-methylisopropyl and the 3,3-methyl-*t*-butylglutaric acids. Undoubtedly, steric hindrance plus temperature effect (acetyl chloride, bp 51°) were operating to prevent anhydride formation in the *trans*-acid of Howles.

Stuart-Briegleb models were constructed for diacids IV, V and VIII to observe steric hindrance to anhydride formation. The preferred configuration to permit the maximum amount of free rotation appeared as shown in Figure 2. If free rotation of the ethyl groups occurred, the carboxyl groups could be prevented from reacting to form the anhydride. If one were permitted to go to higher temperatures (greater than 90°), the distortion in bond angles and lengths could possibly allow anhydride formation. This may explain why diacid VIII could not be converted to the anhydride while Bruice was successful in synthesizing the analogous anhydride of 3,3-diethylglutaric acid.

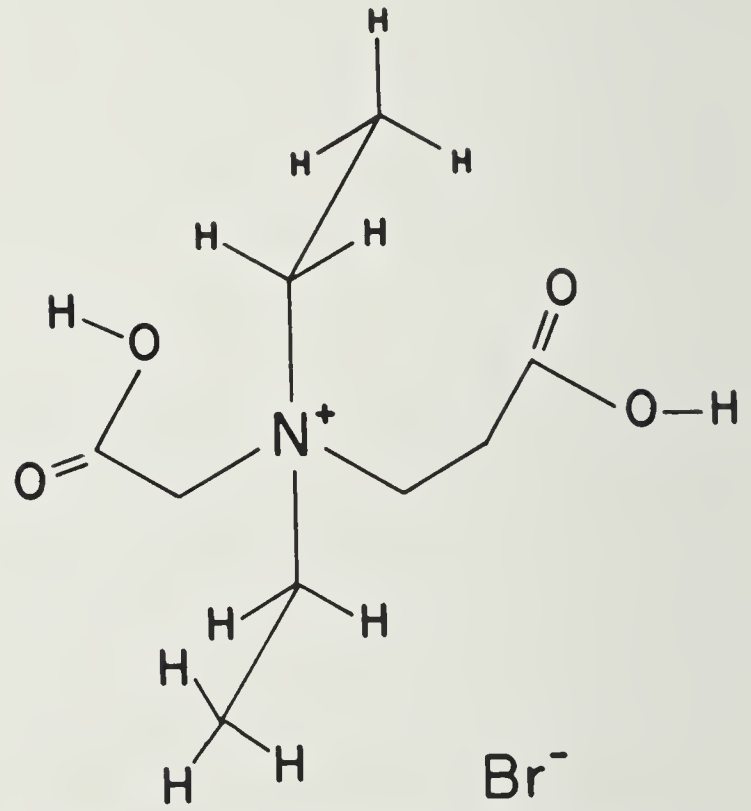

FIGURE 2. Conformation of Dicarboxymethyldiethylammonium Bromide.

In addition to the restriction in reflux temperature for diacid VIII (90°), it should also be emphasized that all of the quaternary ammonium dibasic acids (IV, V and VIII) were fairly insoluble in acetic anhydride. This probably was not the case with the 3,3-substituted glutaric acids of Bruice.

Acknowledgments

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RECENT RANGE ADJUSTMENTS AND HYBRIDIZATION OF *NOTROPIS LUTRENSIS* AND *NOTROPIS SPILOPTERUS* IN ILLINOIS

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ABSTRACT. — Mass hybridization and competitive displacement among Illinois populations of minnows of the subgenus *Cyprinella* are analyzed. Hybridization between *N. lutrensis* and *N. spilopterus* appears to be dependent upon turbidity, both as a factor leading to the invasion of the range of *N. spilopterus* by *N. lutrensis* and to the breakdown of their reproductive isolating mechanisms. A comparison of current and 1908 distributions reveals that the invasion of *N. lutrensis* into streams occupied by *N. spilopterus* has subsequently led to the displacement of *N. spilopterus*.

Notropis lutrensis and *N. spilopterus* are closely related minnows of the subgenus *Cyprinella* (Gibbs, 1957*a*). The close relationship between the two species and recent invasion in Illinois of *N. lutrensis* into areas occupied by *N. spilopterus* have resulted in mass hybridization between the two species and in the displacement of *N. spilopterus* from much of its former range. The principal areas of hybridization are in the middle portions of the Green and Sangamon river drainages.

METHODS

On October 5 and 26, 1969, collcting trips were made to the middle Green River system, one of the areas known to have a high incidence of *N. lutrensis* x *spilopterus* hybrids. Various habitats were sampled to determine the habitat preference of the hybirds and to obtain as many specimens as possible. Notes on ecological conditions and associated species were made at each collecting site. Specimens were preserved in 10-percent formalin at capture. Material collected in 1969 was supplemented with specimens from the collection of the Illinois Natural History Survey.

Determinations of body depth to standard length ratios, counts of lateral-line scales, and counts of anal rays were made following methods outlined by Hubbs and Lagler (1958). These three characters have been consistently used by other investigators to separate *N. lutrensis* and *N. spilopterus* and were assumed to be ones which could easily show indications of introgression. Measurements were taken on 100 hybrids, 100 specimens of each parent species collected within 50 miles of the hybrid swarm locality, 100 *N. lutrensis* from central and southern Illinois (Mississippi and Illinois drainages), and 100 *N. spilopterus* from eastern Illinois (Wabash drainage).

ILLINOIS DISTRIBUTIONS OF *N. LUTRENSIS* AND *N. SPILOPTERUS*

Forbes and Richardson (1908) found *N. lutrensis* generally widespread in the Mississippi drainage of Illinois and especially common in the westernmost counties of the state and in the western tributaries of the Illinois River (Fig. 1). Results of

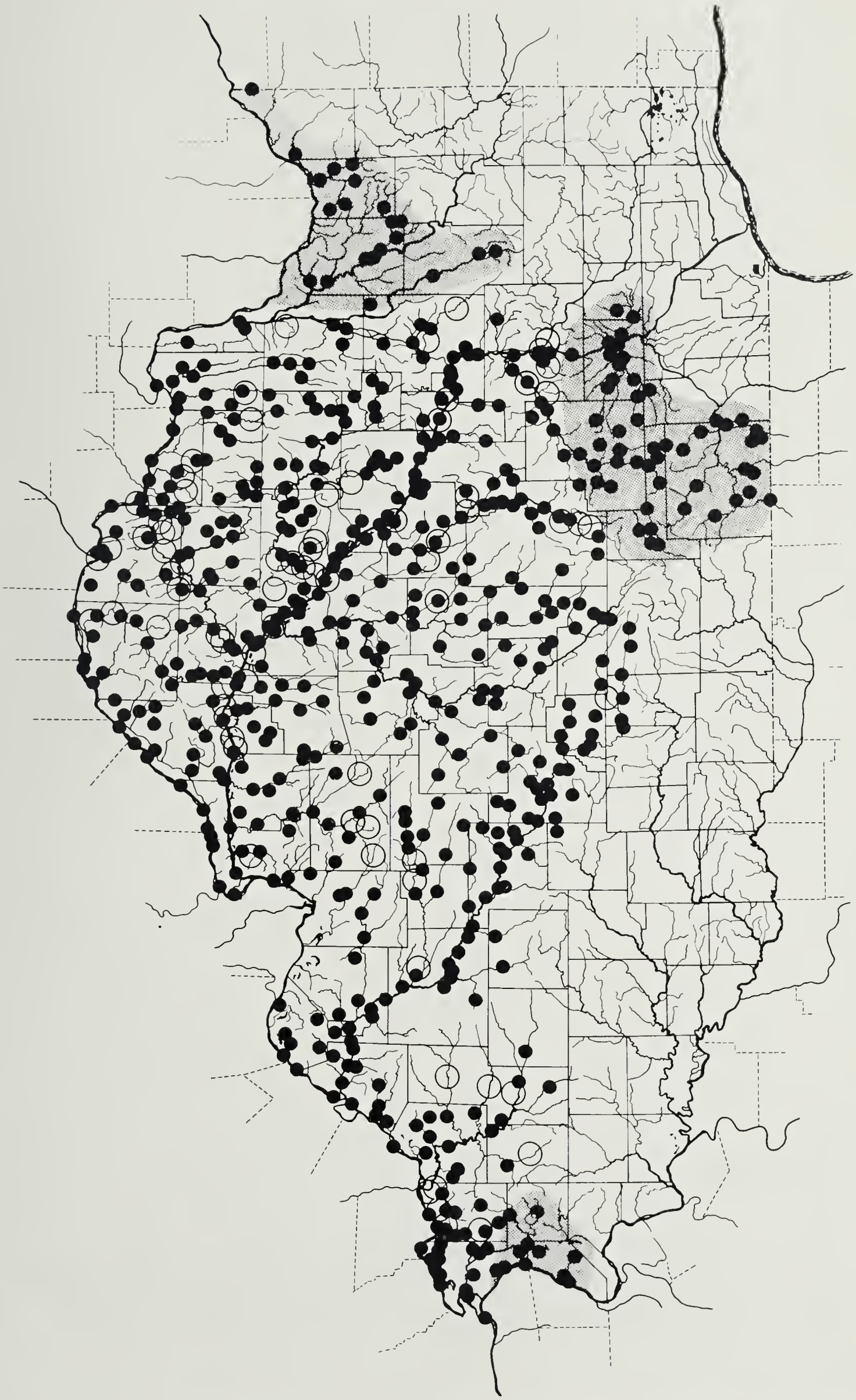

FIGURE 1. Distribution of *N. lutrensis*. Open circles denote 1908 locality records; solid circles denote 1950-69 locality records. The shaded areas indicate the major range expansions which occurred from 1908 to the present.

a current survey of Illinois fishes indicate a similar distribution except for range extensions to the east and north. The species is now extremely common throughout its range in Illinois and usually present in large populations.

The habitats occupied by *N. lutrensis* are quite variable, ranging from small intermittent streams to medium and occasionally large rivers; however, the largest populations occur in small to medium-size streams. The species is taken over a variety of bottom types, which vary from clean sand or gravel to almost pure silt. Its tolerance for silt is undoubtedly a major factor contributing to the present abundance of the species in the agricultural areas of Illinois.

The distribution of *N. spilopterus* in Illinois has changed dramatically from the time Forbes and Richardson made their collections to the present. Formerly the species was widespread throughout most of Illinois, being absent only in those areas bordering or near the Mississippi River in the southern one-half of the state (Fig. 2). The species is still abundant in the Wabash drainage and in northern Illinois but has been nearly extirpated in the entire Mississippi drainage of the southern three-fourths of the state. The only recent records for the lower Mississippi drainages are six from the Sangamon River system and one from the Kaskaskia River system.

N. spilopterus is most often encountered alongside sand or gravel bars in streams and rivers of moderate current. Although its abundance in the Wabash drainage suggests a preference for clear and undisturbed waters, it is a common species in the small, often-turbid streams characteristic of the northern portion of its Illinois range.

The concurrence of reduction in range of *N. spilopterus* and expansion of range of *N. lutrensis* suggests an ecological incompatibility between the two species. Examination of locality records reveals that many of the streams invaded by *N. lutrensis* were occupied at the time by *N. spilopterus,* and that *N. spilopterus* disappeared subsequent to that invasion (Fig. 3; and compare 1908 distributions in Fig. 1 and Fig. 2).

The complementary (parapatric) nature of their present ranges indicates that the two species are strongly competitive, and in instances of range convergence *N. lutrensis* eventually displaces *N. spilopterus.* Two of the areas where *N. lutrensis* has invaded the range of *N. spilopterus* are now populated by hybrid swarms (Fig. 3).

Hybridization

Reports by Forbes and Richardson (1908) and Thompson (1935) of hybrids between *N. lutrensis* and *N. "whipplii"* (=*spilopterus*) in Illinois were questioned by Gibbs (1957*b*) who postulated that the forms, rather than hybrids, were extreme representatives of *N. spilopterus hypsisomatus,* a subspecies "approaching *Notropis lutrensis* in general configuration." However, recent collections by Illinois Natural History Survey personnel have included specimens that are impossible to assign to either *N. lutrensis* or *N. spilopterus* using the characters

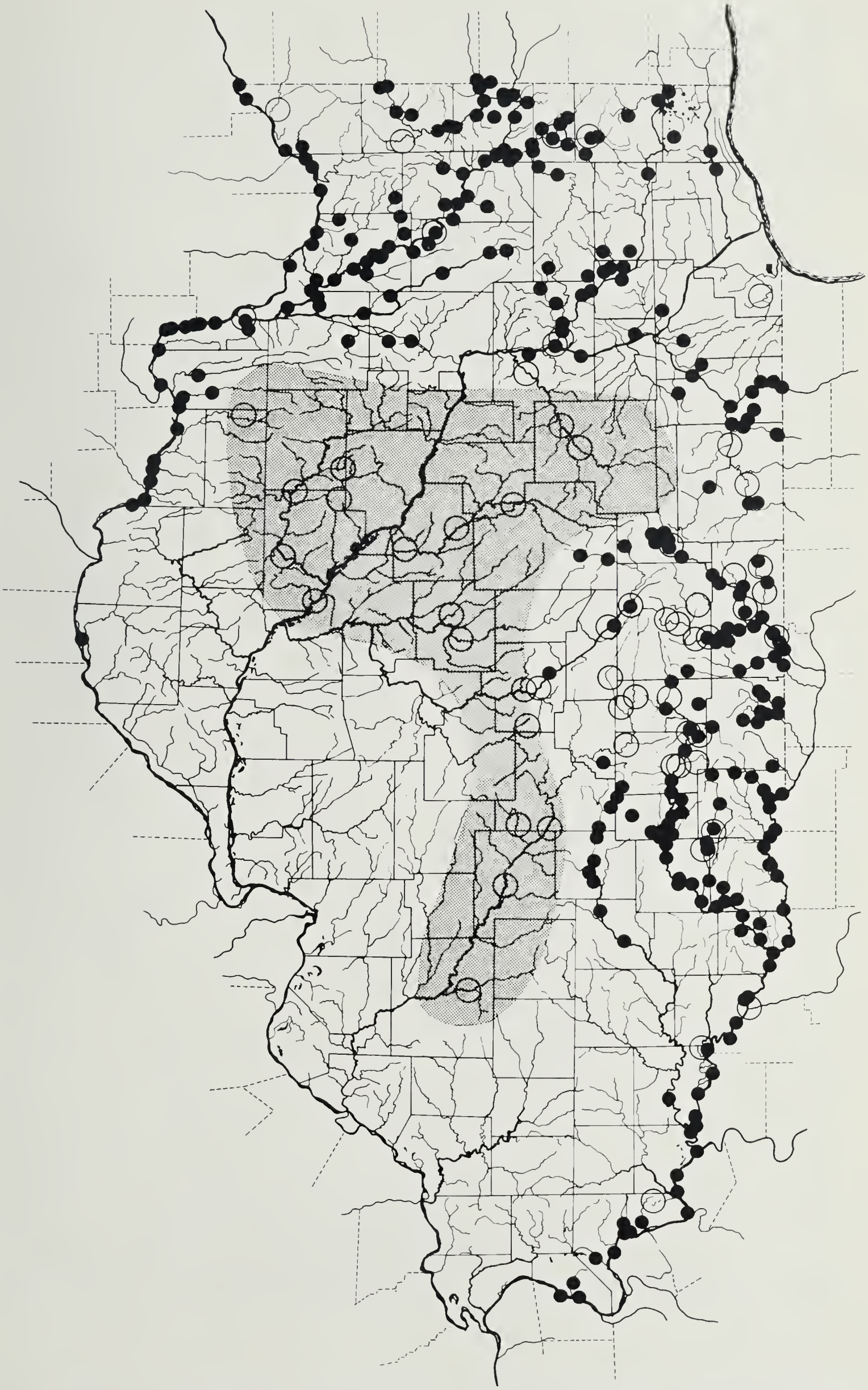

FIGURE 2. Distribution of *N. spilopterus*. Symbols as in Fig. 1. The shaded area indicates the range reduction which occurred from 1908 to the present.

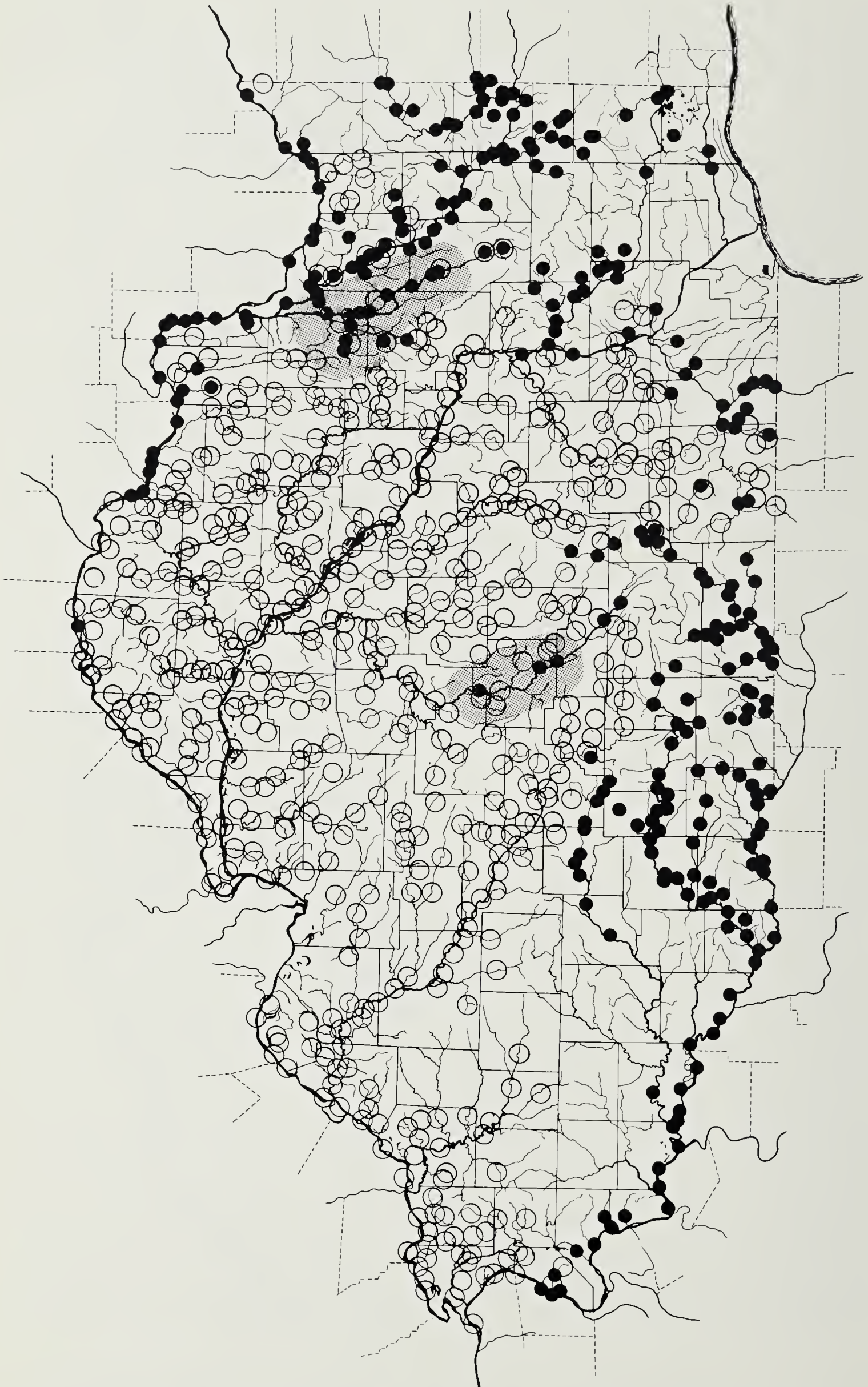

FIGURE 3. Present parapatry of *N. lutrensis* (open circles) and *N. spilopterus* (solid circles). The two shaded areas are the present-day localities of hybrid swarms.

suggested by Gibbs (*ibid.*) and are definitely hybrids.

As *N. lutrensis* moves into streams occupied by *N. spilopterus,* the encounter at least occasionally results in hybridization, and in certain instances in the formation of hybrid swarms. Such a hybrid swarm occurs in the Green River system.

The middle Green River is in a lowland sand area and is almost entirely sand-bottom with slow or moderate current. Tributaries to the river are also predominately sand bottom; however, extensive agricultural use of the surrounding land has inundated them with silt. Direct information on the history of siltation in the area is not available, but changes that have occurred in the fish fauna are an indication of its severity. Five collections by Forbes and Richardson included 56 species of fishes among which were such clear-water forms as *Notropis rubellus, N. heterodon, N. boops, Erimyzon oblongus,* and *Etheostoma exile.* Eighteen collections from 1950 to the present have yielded only 38 species, including none of the above-listed clear-water forms. Species present now but not before include forms notably tolerant of silty water, such as *Cyprinus carpio, Pimephales promelas,* and *Semotilus atromaculatus.*

Hybridization between *N. lutrensis* and *N. spilopterus* appears to be dependent upon turbidity, both as a factor leading to the invasion of a stream by *N. lutrensis,* and to the breakdown of reproductive isolating mechanisms which are probably manifestations of species recognition. The bright yellow fins of breeding male *N. spilopterus* and bright red fins of breeding male *N. lutrensis* suggest that species recognition in both species is visual. In addition, sounds emitted by several species of *Cyprinella* (including *N. lutrensis*) during courtship (Delco, 1960; Winn & Stout, 1960) suggest audio recognition as an isolating mechanism. A high concentration of silt particles in suspension in the breeding habitat could disrupt the transmission of both light and sound and result in the improper identification of spawning partners.

Most of the hybrids were recognized as such at the time of capture because of the difficulty in assigning them to either *N. lutrensis* or *N. spilopterus.* Several collections were composed of a few specimens that were assignable to one or the other species but consisted predominately of specimens that could not be assigned.

The wide range of variation and high percentage of hybrids in the collections indicated that the hybrids were not all F_1 progeny and consequently were partially fertile. Progeny from backcrosses with one or both parent species, from crosses among the hybrids themselves, or both were probably represented in the collections.

The sample of 100 hybrids had mean lateral-line-scale and anal-ray counts intermediate between those of the parent species (Table 1 and Fig. 4), as expected when considering the large morphological variation expressed by the hybrids. Anal-ray counts for the hybrids were closer to counts for *N. spilopterus* than for *N. lutrensis.*

The mean ratio of standard length into body depth for the hybrids was

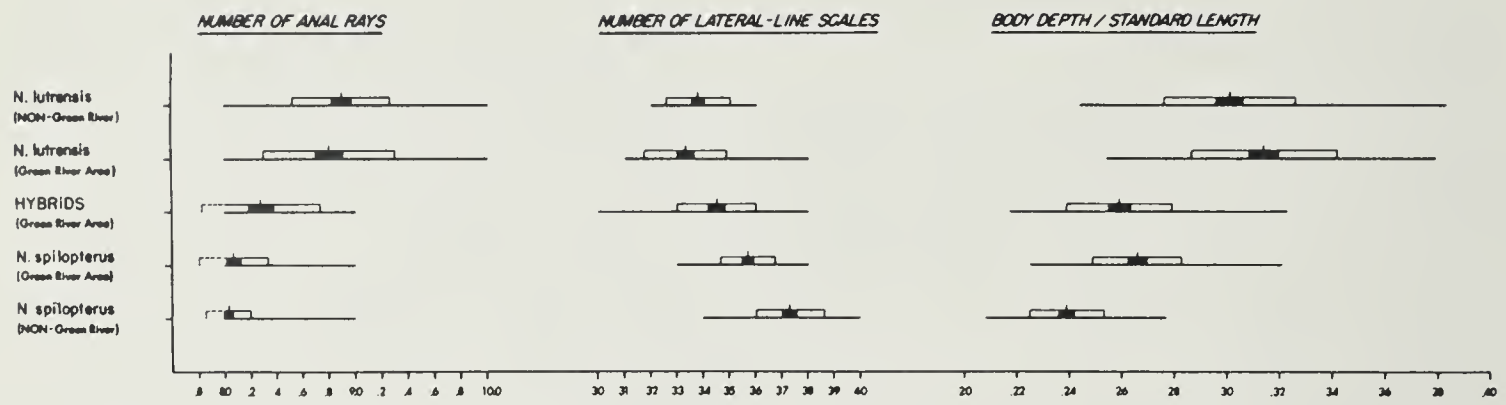
NUMBER OF ANAL RAYS
NUMBER OF LATERAL-LINE SCALES
BODY DEPTH / STANDARD LENGTH
N. lutrensis (NON-Green River)
N. lutrensis (Green River Area)
HYBRIDS (Green River Area)
N. spilopterus (Green River Area)
N spilopterus (NON-Green River)

FIGURE 4. Analysis of characters examined on five samples of minnows. Each sample contained 100 specimens. The horizontal line indicates range; the vertical line, mean; the hollow rectangle, one standard deviation to either side of the mean; and the black rectangle, two standard errors to either side of the mean.

less than the means of the two *N. lutrensis* samples and one of the *N. spilopterus* samples, but larger than the non-Green-River sample of *N. spilopterus*.

The characteristics of the Green-River samples of the parent species were more hybrid-like than those of the non-Green-River samples. The intermediate expressions may be manifestations of introgression or may be due to the presence of unrecognizable hybrids in the samples considered as Green-River *N. spilopterus* and *N. lutrensis*.

The range adjustments of the two minnows and knowledge that they hybridize suggest the following sequence of events: an initial occupation of a stream by *N. spilopterus;* invasion of the stream by *N. lutrensis* (moving eastward and northward); hybridization; subsequent increasing influence of *N. lutrensis* as more invasions occur; and eventual eradication of both *N. spilopterus* and hybrids.

Hybrid vigor may account for the initial fitness of the hybrids. The eventual replacement by *N. lutrensis* indicates either that the hybrids lose fitness in successive generations and disappear from the area, or more likely, are displaced by the invading *N. lutrensis*.

PERMANENT EFFECTS ON PARENT SPECIES

Hybrids are known to become common in an area where there has been a major change in the environment, but the identity of the hybrids in subsequent generations depends upon the amount of backcrossing with one or both parent species (Mettler & Gregg, 1969). In a *N. lutrensis* x *spilopterus* swarm, a continual influx of *N. lutrensis* would create an increasing proportion of backcross progeny with the majority of its chromosome complement derived from *N. lutrensis* and with decreasing evidence of *N. spilopterus* influence.

Thompson (1935) reported a hybrid swarm of *N. lutrensis* x *spilopterus* "in the region about the mouth of the Sangamon river near Chandlerville and Beardstown." Both the hybrids and *N. spilopterus* have since been replaced in that area by *N. lutrensis*. Specimens of *N. lutrensis* from that area and other areas of Illinois formerly occupied by *N. spilopterus* show no morphological

TABLE 1. Analysis of characters examined on five samples of minnows. Each sample contained 100 specimens.

	No. of Anal Rays		No. of Lateral Line Scales			Standard Length Into Body Depth		
	Range	X	Range	X	SD	Range	X	SD
N. lutrensis (non-Green River)	8–10	8.89	32–36	33.78	1.26	.244–.383	.301	.025
N. lutrensis (Green River area)	8–10	8.80	31–38	33.30	1.44	.254–.379	.314	.028
Hybrids (Green River area)	8–9	8.28	30–38	34.48	1.44	.217–.323	.259	.020
N. spilopterus (Green River area)	8–9	8.07	33–38	35.71	.99	.225–.321	.266	.017
N. spilopterus (non-Green River)	8–9	8.03	34–40	37.33	1.13	.208–.277	.239	.014

influence of *N. spilopterus*. Thus, although measurements taken on specimens from near the hybrid swarm locality suggested that some introgression was occurring, no permanent influence is discernible.

There is no reason to doubt that *N. lutrensis* will complete its purge of *N. spilopterus* from the Mississippi drainage of Illinois. A recent (within the last five years) invasion of *N. lutrensis* into the Wabash drainage (upper Middle Fork, Ford Co., Illinois) raises the possibility that the range of *N. spilopterus* will be even further reduced. In fact, *N. spilopterus* may one day be extirpated from Illinois, and *N. lutrensis* may have a state-wide distribution. However, the tributaries of the Wabash are, in general, not as silt-laden as those of the Illinois and Mississippi drainages, and the lack of silt could reduce, if not eliminate, the basis for competitive exclusion.

Range Relationships With Other Species of *CYPRINELLA*

In addition to *N. lutrensis* and *N. spilopterus,* two other species of *Cyprinella* occur in Illinois, *N. venustus* and *N. whipplei*. *N. venustus* is known from one drainage system in southern Illinois, in which it is sympatric with *N. lutrensis*. Hybrids between the two species are fairly common, indicating that reproductive isolating mechanisms occasionally break down. There is, however, no indication that competitive displacement will occur. Both species had invaded the drainage prior to 1908 and have since been able to maintain sizeable populations.

Hubbs and Strawn (1956) concluded that high turbidity was a contributing factor in the hybridization between *N. lutrensis* and *N. venustus* in Texas.

In contrast to the relationship between *N. venustus* and *N. lutrensis,* no evidence of hybridization between *N. whipplei* and *N. lutrensis* has been found, but evidence for competitive exclusion does exist. The range of *N. whipplei* has been considerably reduced since 1908 in areas now occupied by *N. lutrensis,* and it is plausible that *N. whipplei,* like *N. spilopterus,* finds *N. lutrensis* ecologically incompatible.

Acknowledgments

We wish to express our appreciation to Dr. Philip W. Smith, Illinois Natural History Survey, for the locality data presented in the distribution maps and for offering helpful comments on the manuscript; to Mr. Richard M. Sheets, Survey artist, for executing Figure 4; and to Mr. Wilmer M. Zehr, Survey photographer, for providing the photographs.

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SOCIOECONOMIC HEALTH OF ILLINOIS MUNICIPALITIES

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Abstract. — A composite index of socioeconomic health was developed from a linear combination of standard scores on five fundamental attributes for the largest cities in Illinois. The cities are ranked on each of the attributes and on the composite index. Spatial and class variations are noted.

The term "socioeconomic health" is a composite expression of the various social and economic characteristics of a place. For purposes of comparison, a place with a high socioeconomic health level is in the aggregate beset with fewer pressing problems than one with a low level of socioeconomic health. The spatial variation of this phenomenon was first assessed quantitatively by Thompson *et al* (1962) in a factor analytic study of New York counties. Because of its obvious significance, this study might have provided the impetus for a number of such analyses in spite of certain statistical and procedural shortcomings. However, the Thompson paper remains the only example of its kind in the geographical literature. A variation of the method is presented here in a study of socioeconomic characteristics of urban places.

In brief, the study area is the state of Illinois and the observational units are its 41 largest municipalities in 1967 (Figure 1), although the analysis pertains to the early 1960's for reasons of data availability. All but five cities are located in SMSA counties. Principal components analysis was used to derive five fundamental socioeconomic attributes from a set of 31 population free indices. The attributes were quantified in order to classify the cities and used in linear combination in the construction of a synthetic measure of socioeconomic health. The index and a ranking of the cities thereon not only illuminates the spatial variation of level of socioeconomic health of Illinois' urban centers, but should prove useful to all disciplines concerned with the solution of contemporary urban problems, particularly in view of the impending availability of the 1970 Census of Population data.

Notation

Denote the following:

Z—N x m matrix of standard scores

R—m x m matrix of Pearson product moment correlations

P—m x p matrix of correlations between standardized variables and principal components

P′—m x p orthogonal rotation of P

C—N x p matrix of standard scores on P′

N is the number of urban places (41), m is the number of socioeconomic indices (31), and p is the number of basic dimensions in R (5).

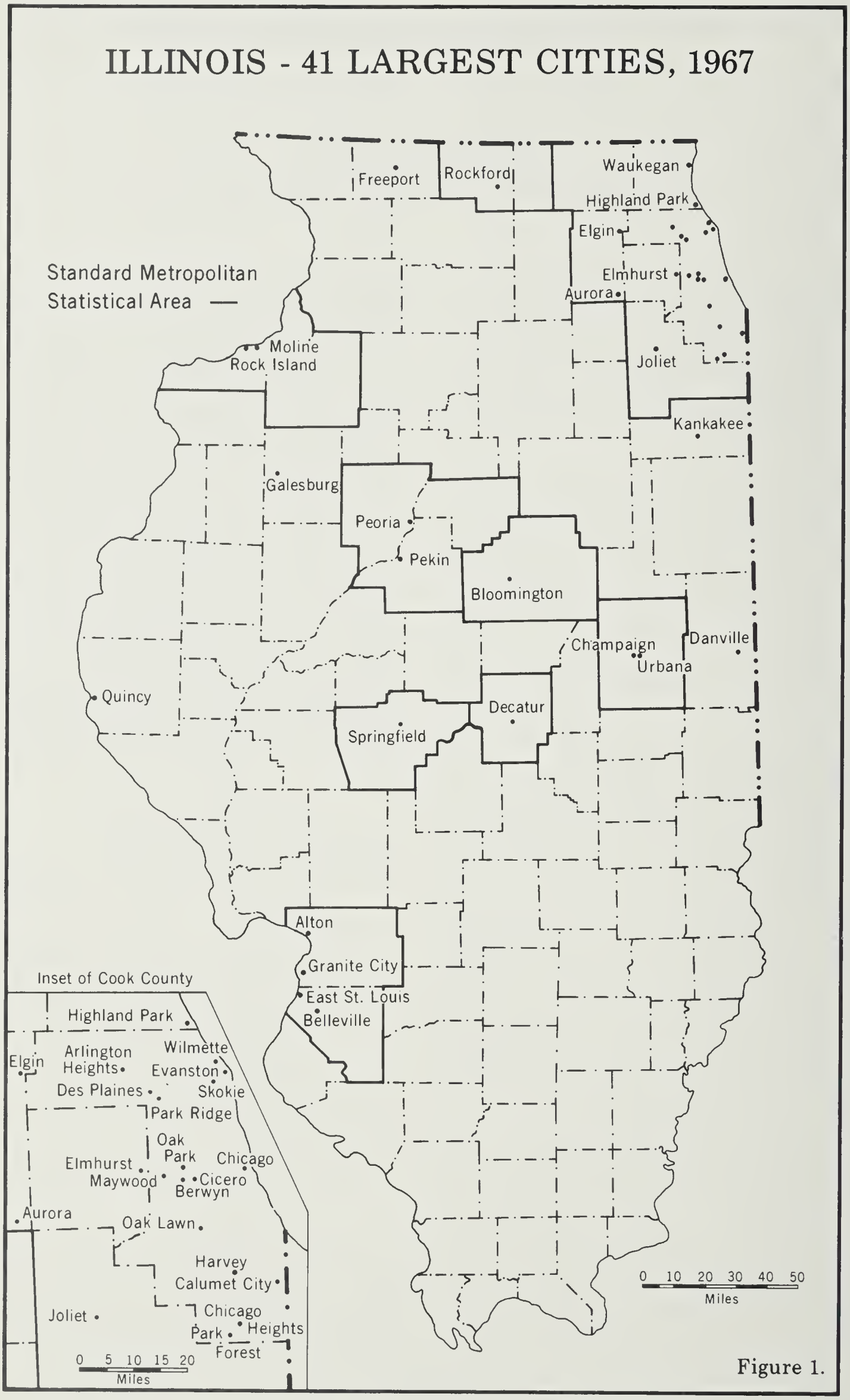

ILLINOIS - 41 LARGEST CITIES, 1967
Standard Metropolitan Statistical Area —
Freeport
Rockford
Waukegan
Highland Park
Elgin
Elmhurst
Aurora
Joliet
Moline
Rock Island
Kankakee
Galesburg
Peoria
Pekin
Bloomington
Champaign
Urbana
Danville
Quincy
Decatur
Springfield
Alton
Granite City
East St. Louis
Belleville
0 10 20 30 40 50
Miles
Inset of Cook County
Highland Park
Elgin
Arlington Heights
Wilmette
Evanston
Skokie
Des Plaines
Park Ridge
Oak Park
Elmhurst
Chicago
Maywood
Cicero
Berwyn
Aurora
Oak Lawn
Harvey
Calumet City
Joliet
Chicago Heights
Park Forest
0 5 10 15 20
Miles

Figure 1.

Principal Components Analysis

Each variable (Table 1) was transformed into its common logarithm and standardized. The correlations between the standard scores (R) were subjected to a principal components analysis, collapsing the original indices into mutually exclusive attributes: $(z_{x_1}, z_{x_2}, \ldots, z_{x_{31}})$ was transformed into a new set of orthogonal vectors or principal components $(P_1, P_2, \ldots, P_{31})$. Those five principal components whose

Table 1. Socioeconomic Indices.

Variable	Code	Description
1	PD	Population density per square mile (1960)
2	PG	Population growth (1960 population as percent of 1950 population)
3	PN	Percent nonwhite population (1960)
4	PF	Percent foreign born population (1960)
5	MA	Median age of population (1960)
6	PS	Percent of population 65 years of age and older (1960)
7	AP	Average number of persons per household (1960)
8	SH	Percent of population residing in same household as in 1955 (1960)
9	BDR	Birth/Death Ratio (1964)
10	FR	Fertility ratio (1960)
11	MS	Median school years completed for persons 25 years of age and older (1960)
12	PHS	Percent of population 25 and older completing high school or more (1960)
13	PM	Percent of non-agricultural workers employed in manufacturing (1960)
14	PRT	Percent of non-agricultural workers employed in retail and wholesale trade (1960)
15	PWC	Percent of non-agricultural workers employed in white collar occupations (1960)
16	MFI	Median family income (1960)
17	PFI	Percent of families having less than $3,000 income (1960)
18	PSD	Percent of dwelling units classified as sound with all plumbing facilities (1960)
19	PSF	Percent of population residing in single family dwelling units (1960)
20	POO	Percent of dwelling units occupied by owner (1960)
21	MVO	Median value of owner occupied dwelling in 000 dollars (1960)
22	MGR	Median gross monthly rent, renter occupied dwelling (1960)
23	AIM	Average income, manufacturing production employee (1963)
24	MP	Manufacturing productivity (1963)*
25	AIR	Average income, retail trade employee (1963)
26	PCW	Per capita sales, retail trade (1963)
27	AIW	Average income, wholesale trade employee (1963)
28	NSE	Number of service establishments per 1,000 population (1963)
29	PCT	Per capita real and personal property tax paid (1964-65)
30	PCG	Per capita government expenditures, excluding capital outlay (1964-65)
31	NGE	Number of full-time government employees per 1,000 population (1964-65)

* Value added by manufacturing divided by total number of manufacturing production employees.

Source: U. S. Bureau of Census (1967, Table 4). Some indices are in modified form and others were calculated from data in the above.

eigenvalues (λ_i) are two or larger (Table 2) are considered to be the basic dimensions in R or the fundamental socioeconomic attributes of Illinois' urban places. Their corresponding eigenvalues are 9.98, 5.49, 3.14, 2.89, and 2.11, respectively, indicative of their order of relative importance, and account for approximately 76 percent of the variance in R.

Mathematically, the eigenvalues are the latent roots in the m characteristic equations which set the determinant of R at zero:

$$\begin{vmatrix} 1-\lambda & r_{12} & \dots & r_{1m} \\ r_{21} & 1-\lambda & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{m1} & r_{m2} & \dots & 1-\lambda \end{vmatrix} = 0 \qquad (1)$$

Given that p_{ij} is the correlation between the ith variable and jth principal component or the ith coefficient of the jth component, a series of equations of the following form is developed:

$$\begin{aligned} p^2_{11} + p^2_{21} + \dots + p^2_{m1} &= \lambda_1 \\ p^2_{12} + p^2_{22} + \dots + p^2_{m2} &= \lambda_2 \\ \dots\dots\dots\dots\dots\dots\dots\dots & \qquad (2) \\ p^2_{1m} + p^2_{2m} + \dots + p^2_{mm} &= \lambda_m \end{aligned}$$

The function of the first principal component is to resolve a maximum amount of variance in R; succeeding principal components resolve as much as possible the remaining variance. Thus, it is necessary to maximize λ_1 initially, and Lagrangian multipliers (see Harman, 1967, pp. 136-142; King, 1969, pp. 172-173) are used to obtain

$$\begin{bmatrix} 1-\lambda & r_{12} & \dots & r_{1m} \\ r_{21} & 1-\lambda & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{m1} & r_{m2} & \dots & 1-\lambda \end{bmatrix} \begin{bmatrix} p_{11} \\ p_{21} \\ \dots \\ p_{m1} \end{bmatrix} = 0 \qquad (3)$$

The first root is the eigenvalue corresponding to P_1 and the remaining roots are the largest roots of $P_2, P_3, \dots, P_m$, respectively. The coefficients ($p_{11}, p_{21}, \dots, p_{m1}$) of P_1 are obtained by scaling its eigenvector by λ_1:

$$p_{i1} = a_{i1} (\lambda_1)^{\frac{1}{2}} \qquad (4)$$

The coefficients of $P_2, P_3, \dots, P_m$ are obtained by similar operations on the residual correlation matrices ($R - PP^t$) until $p = m$, $\Sigma\lambda_i = m$, and $PP^t = R$.

Principal Socioeconomic Attributes

Labeling of the attributes was facilitated by rotating P to P′, using a varimax criterion (see Harman, 1967, pp. 304-313) in which P is rotated so as to maximize the variance between the principal components, subject to maintaining each variable's communality. This has the effect of increasing the absolute magnitude of "loadings" whose absolute values are initially high and minimizing those whose values are low.

Using the magnitudes and signs of the rotated coefficients (Table 2), the principal components were identified as : P_1 — socioeconomic achievement; P_2 — demographic dynamics; P_3 — unimportance of man-

TABLE 2. Summary of principal components analysis.

Attribute		P_1	P_2	P_3	P_4	P_5
Eigenvalue		9.98	5.49	3.14	2.89	2.11
Percent of total variance in R		32.2	17.7	10.1	9.3	6.8
$\lvert p'_{ij} \rvert \geq .30$		p'_{i1}	p'_{i2}	p'_{i3}	p'_{i4}	p'_{i5}
Variable	Code					
1	PD				—.81	
2	PG	.61	.60		.37	
3	PN	—.65			—.38	
4	PF	.60			—.59	
5	MA		—.92			
6	PS	—.45	—.80			
7	AP	.56	.66		.35	
8	SH		—.77	—.48		
9	BDR		.87			
10	FR		.81		.39	
11	MS	.69		.57		
12	PHS	.53	.36	.57		
13	PM			—.89		
14	PRT			.30		.46
15	PWC	.74		.59		
16	MFI	.94				
17	PFI	—.94				
18	PSD	.93				
19	PSF		.30		.86	
20	POO	.42			.84	
21	MVO	.92				
22	MGR	.94				
23	AIM			—.64		
24	MP				—.43	
25	AIR					
26	PCR					.73
27	AIW	.60			—.44	
28	NSE	—.60	—.45			.42
29	PCT					.49
30	PCG					.86
31	NGE					.79

ufacturing; P_4 — residential site availability; P_5 — commercial and governmental services. The socio-economic achievement component (P_1) is manifested by high positive correlations with indices of affluence, educational level of the population, and value of dwelling unit. P_2 is indicative of youthfulness of the population and the ability of a city to attract and maintain population as evidenced by population growth through both in-migration and natural increase. P_3 is indica-

tive of economic diversification, or specifically of a city's lack of dependence upon manufacturing as the major source of personal income for its residents. P_4 correlates positively with indices of single family housing, availability of which is ultimately dependent upon site availability and lack of competing and often noxious land uses. P_5 correlates positively with strength of the commercial and governmental services base, and implicitly with disposable income and ability (or willingness) to support local government, notwithstanding that Springfield is one of those cities under study.

Scores on Rotated Principal Components

The standardized logarithms of the original socioeconomic indices were condensed into orthogonal, standardized measures of the rotated attributes in order that classes of cities might be elicited with a minimum distance squared grouping algorithm (see Berry, 1961; Marble, 1967, pp. 23-34), using their component score vectors as image points in Euclidian space, and that their socioeconomic health be evaluated. Denote an N x p matrix of such scores by C:

$$C = ZR^{-1}P' \qquad (5)$$

Then, c_{ij} is the standardized magnitude of P'_{ij} at the ith urban place. Zero is of a higher order of magnitude than a negative number; e.g., a positive score on P'_1 is indicative of a high socioeconomic achievement level, whereas a negative score indicates lack of achievement. A positive score on P'_2 indicates a dynamic population, however a negative score is characteristic of either demographic inertia or a declining population because of out-migration. A positive score on P'_3 suggests that a city's economic base is attributable to the tertiary and quaternary sectors: a negative score suggests that a city has an essentially manufacturing based economic structure. Similar reasoning may be applied to both P'_4 and P'_5.

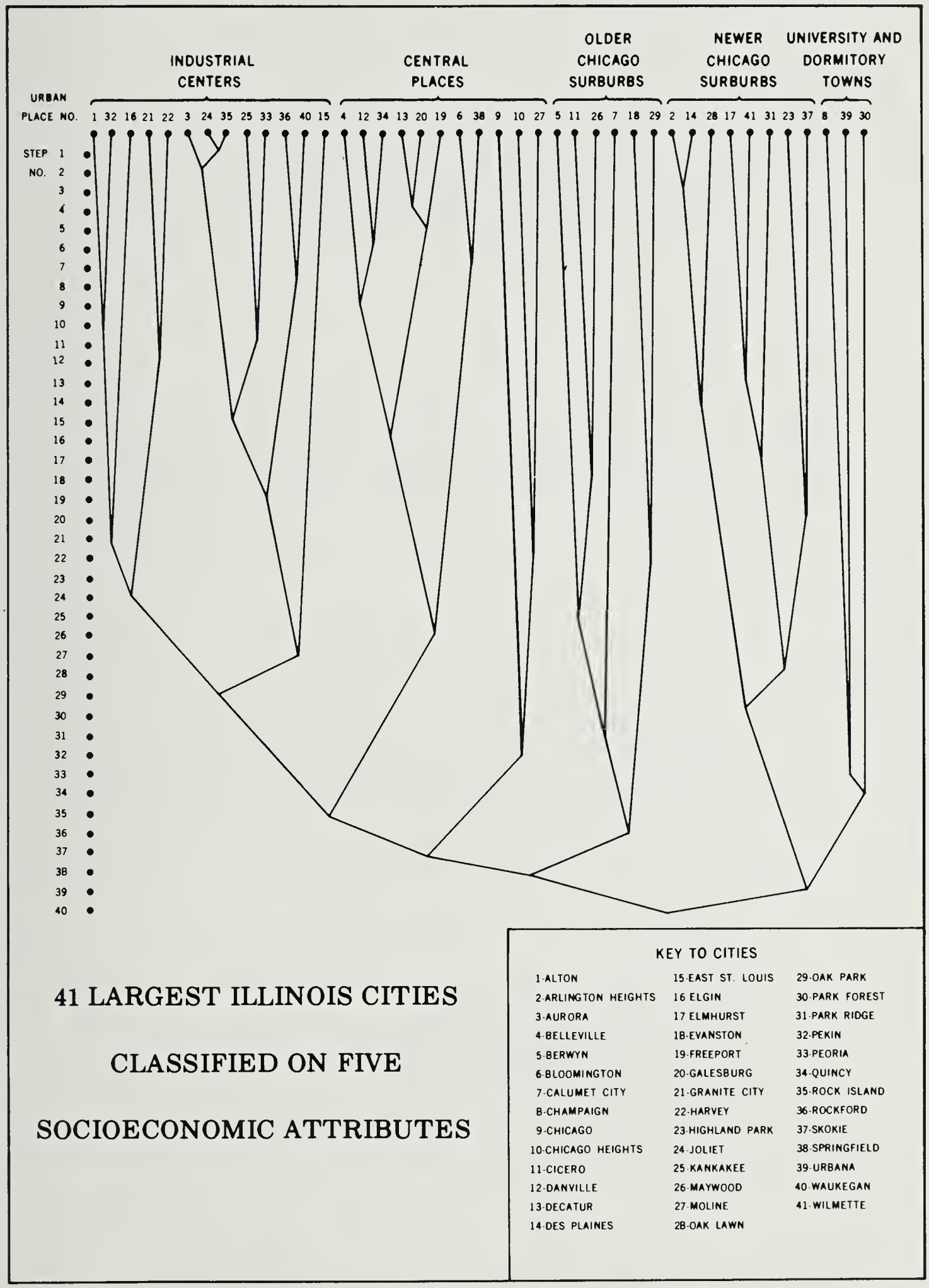
Classes of Urban Places

The grouping "tree" for the classification procedure is shown in Figure 2. Five classes (designated industrial centers, n = 13; central places, n = 11, serving and supported by smaller centers and the dispersed population; older Chicago SMSA suburbs, n = 6; newer Chicago suburbs, n = 8; and university and dormitory towns, n = 3) were elicited by the 36th iteration. Degrees of similarity between classes may be noted by perusing later combinations. Industrial centers are combined with the central places at step 37, followed by combination of this pair with the older Chicago suburbs at step 38. The newer suburbs are combined with the university-dormitory town group at step 39.

Rankings on Principal Components

The cities are ranked on the attributes in Table 3. Those cities ranking highest on socioeconomic achievement are clustered in the Chicago SMSA and include both established and newer suburbs of Chicago as defined in the foregoing. Nearly all downstate centers, including central places, industrial centers, and the college communities of Champaign and Urbana rank low on this dimension.

The newer Chicago satellites, Champaign-Urbana, and a number



of Chicago area and downstate industrial centers rank high on the demographic dynamics component, whereas the older, essentially impacted suburbs (e.g., Oak Park and Evanston) and those with a high degree of ethnic concentration (e.g., Berwyn, Cicero, and Highland Park) rank low, as do most downstate central places which are large-

TABLE 3. Largest Illinois cities ranked on socioeconomic attributes*.

P_1'—Socioeconomic Achievement	P_2'—Demographic Dynamics	P_3'—Unimportance Manufacturing	P_4'—Residential Site Availability	P_5'—Commercial and Governmental Services
1—Park Ridge	1—Park Forest	1—Urbana	1—Oak Park	1—Moline
Wilmette	Champaign	Champaign	Highland Park	Skokie
Skokie	Chicago Heights	Bloomington	Arlington Heights	Highland Park
Elmhurst	Oak Lawn	Evanston	Belleville	Chicago
5—Arlington Heights	5—Arlington Heights	5—Oak Park	5—Pekin	5—Champaign
Highland Park	E. St. Louis	Wilmette	Park Ridge	Chicago Heights
Park Forest	Skokie	Springfield	Danville	Springfield
Oak Park	Waukegan	Park Ridge	Des Plaines	Peoria
Berwyn	Harvey	Park Forest	Quincy	Evanston
10—Des Plaines	10—Des Plaines	10—Highland Park	10—Decatur	10—Bloomington
Evanston	Calumet City	Decatur	Alton	Wilmette
Oak Lawn	Granite City	Galesburg	Freeport	Rockford
Cicero	Urbana	Quincy	Galesburg	Waukegan
Maywood	Chicago	Skokie	15—Bloomington	15—Oak Park
15—Calumet City	15—Rockford	15—Freeport	Kankakee	Kankakee
Elgin	Maywood	Danville	Elmhurst	Danville
———	———	Arlington Heights	Skokie	Rock Island
Waukegan	Kankakee	Belleville	Granite City	Arlington Heights
Aurora	T19—Aurora	———	20—Joliet	20—Belleville
Rockford	T19—Alton	Kankakee	Rock Island	Des Plaines
20—Chicago	T19—Moline	20—Des Plaines	Elgin	———
Moline	21—Peoria	Rock Island	Springfield	Elmhurst
Harvey	Rock Island	Peoria	———	Joliet
Joliet	Joliet	Elmhurst	Aurora	Galesburg
Chicago Heights	Elmhurst	E. St. Louis	25—Rockford	25—Quincy
25—Granite City	25—Wilmette	25—Elgin	Moline	Aurora
Pekin	Decatur	Oak Lawn	Harvey	E. St. Louis
Rock Island	Peoria	Joliet	E. St. Louis	Maywood
Freeport	Galesburg	Pekin	Calumet City	Alton
Belvidere	Danville	Aurora		

TABLE 3. (Continued)

P_1'—Socioeconomic Achievement	P_2'—Demographic Dynamics	P_3'—Unimportance Manufacturing	P_4'—Residential Site Availability	P_5'—Commercial and Governmental Services
30—Urbana	30—Bloomington	30—Berwyn	30—Peoria	30—Harvey
Galesburg	Highland Park	Rockford	Waukegan	Park Ridge
Bloomington	T32.5—Evanston	Waukegan	Park Forest	Elgin
Alton	T32.5—Springfield	Moline	Chicago Heights	Cicero
Springfield	Freeport	Chicago	Oak Park	Freeport
35—Champaign	35—Park Ridge	35—Calumet City	35—Champaign	35—Pekin
Decatur	Belleville	Harvey	Berwyn	Decatur
Peoria	Quincy	Alton	Maywood	Granite City
Kankakee	Elgin	Maywood	Urbana	Berwyn
Quincy	Cicero	Chicago Heights	Cicero	Park Forest
40—Danville	40—Oak Park	40—Granite City	40—Evanston	40—Urbana
E. St. Louis	Berwyn	Cicero	Chicago	Calumet City

* Underline separates those cities with positive scores (above) from those with negative scores (below).

ly sources of young adult migrants to the more attractive Chicago SMSA.

Such traditionally industrially based centers as Cicero, Granite City, Chicago Heights, Chicago, and Moline rank high in terms of degree of dependence on manufacturing. Those cities in which manufacturing is comparatively unimportant as contrasted with the development of the higher order economic sectors include both new and established residential suburbs of Chicago, Champaign-Urbana, and downstate central places of which the outstanding example is Bloomington with its service industry base.

A high degree of residential site availability is characteristic of the newer, less impacted Chicago suburbs (e.g., Oak Lawn, Arlington Heights) as well as by most central places. The impacted suburbs, most industrial centers, Champaign-Urbana, and notably Chicago, rank low on this dimension.

The last attribute, commercial and governmental services, is more difficult to illuminate either spatially or by class. In any event, those cities which have a large proportion of the labor force employed by extra-local governmental agencies rank high (Springfield and Moline), as do many of the more affluent, established suburbs and some central places. At the other extreme, several of the newer suburban towns, particularly those without a high degree of commercial activity or exurban to the extent that governmental services have apparently had neither the time nor the need to develop despite an affluent population, rank low. The commercial-university dichotomy of Champaign-Urbana is particularly in evidence on this dimension.

Apart from any other relationship, the level of this component also appears to vary directly with size of the population and implementation of welfare programs.

Socioeconomic Health Index

A synthetic measure of socioeconomic health was constructed using a linear combination of the scores on the rotated principal components. Since socioeconomic achievement, a dynamic demographic condition, a diversified economic base, availability of land for single family residential construction, and a firm commercial - governmental services base may be considered as contributing to the socioeconomic viability of a city, the index might be written

$$HI_i = c_{i1} + c_{i_2} + c_{i_3} + c_{i4} + c_{i5} \quad (6)$$

where HI is the index score. However, the attributes do not have equal importance, and it is appropriate to scale the component scores, using the eigenvalues as coefficients of the linear combination. Thus, for this analysis,

$$HI_i = 9.98c_{i1} + 5.49c_{i_2} + 2.14c_{i_3} + 2.89c_{i4} + 2.11c_{i5} \quad (7)$$

The index scores and ranks are given in Table 4. The nine highest ranking urban place and thirteen of the highest ranking fourteen are located in the Chicago SMSA, again indicative of a remarkable contiguity effect. Moreover, their suburban nature is indicative of the flow of wealth and population from the inner city to the urban fringe in metropolitan Chicago. Of the Chicago area cities, only Berwyn and Cicero (close-in ethnic concentrations) from the suburbs and Chicago itself rank below the median for the cities

TABLE 4. Largest Illinois cities ranked on socioeconomic health index.

Rank	City	Health Index
1	Park Forest	28.73
2	Skokie	26.29
3	Arlington Heights	24.50
4	Wilmette	20.88
5	Highland Park	20.40
6	Oak Lawn	18.37
7	Park Ridge	18.02
8	Des Plaines	16.29
9	Elmhurst	14.93
10	Champaign	6.17
11	Evanston	3.22
12	Oak Park	1.96
13	Chicago Heights	.95
14	Waukegan	.67
15	Moline	—1.80
16	Calumet City	—2.01
17	Rockford	—2.20
18	Aurora	—2.64
19	Urbana	—2.97
20	Maywood	—2.98
21	Harvey	—4.14
22	Bloomington	—4.80
23	Joliet	—5.51
24	Rock Island	—6.07
25	Pekin	—6.17
26	Galesburg	—6.36
27	Elgin	—7.09
28	Springfield	—7.83
29	Belleville	—7.86
30	Berwyn	—7.96
31	Decatur	—8.29
32	Kankakee	—9.03
33.5	Freeport	—9.21
33.5	Granite City	—9.21
35	Peoria	—9.98
36	Alton	—11.42
37	Chicago	—11.45
38	Cicero	—12.03
39	Danville	—12.19
40	Quincy	—13.75
41	East St. Louis	—17.21

Mean Health Index by Class

Industrial Centers	—6.92
Central Places	—7.51
Older Chicago Suburbs	—3.30
Newer Chicago Suburbs	19.96
University and Dormitory Towns	12.62

under study. Conversely, all St. Louis area cities are below the median. Considered by class (the class means are given in Table 4), most high ranking urban places are suburban, and newer suburbs rank higher than older suburbs. The lowest ranking cities are either indus-

trial centers or central places. Of equal significance, there is also an apparent inverse relationship between the level of a city's socioeconomic health and distance from suburban Chicago.

Acknowledgments

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All phases of the principal components analysis were performed on the IBM System/360-40 digital computer formerly in use at Northern Illinois University, using BMD program BMDO3M (General Factor Analysis). The variables were converted to logarithms with BMD program BMD09S (Transgeneration). See Dixon (1967, pp. 169-184, 421-429) for detailed documentation of these routines. The classification procedure was performed on an IBM System/360-65 at the University of Iowa, Iowa City. See Marble (1967, pp. 22-34) for the program CONGROUP.

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POST-GLACIAL DRAINAGE DIVERSIONS IN A PORTION OF NORTH CENTRAL ILLINOIS

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ABSTRACT. — The drainage system in north-central Illinois bears evidence of several marked drainage diversions in post-glacial times. Original drainage in this area, which was consequent on the glacial landscape, has been extensively modified by the capture of low gradient streams by their more dynamic neighbors. Two streams in particular, Indian Creek and Kyte River, have extended their drainage at the expense of their lower gradient neighbors, Green River, South Branch of Kishwaukee River, and Little Vermilion River.

Stream piracy is the process whereby a stream is able to divert the drainage of a portion of another stream system into its own system (Thornbury, 1969, p. 148). Stream piracy most commonly occurs where two adjacent streams have markedly different gradients, such that the higher gradient stream is able to extend itself headward and intercept a portion of the lower gradient stream. The flow of the lower gradient stream above the point of interception is thereafter diverted into the higher gradient stream by virtue of the latter's lower level. The result is an expansion of the pirating drainage system at the expense of the pirated.

Conditions conducive to stream piracy existed in north-central Illinois following the retreat of the Pleistocene ice sheets. While the glacial ice occupied the land, extensive deposition of glacial drift at the base and margins of the ice completely buried and obliterated the pre-existing bedrock drainage courses. With the retreat of the ice, new drainage systems came into existence on the irregular surface of the drift sheets. For the most part these immediately post-glacial streams were immature consequent streams, flowing down the highly variable regional slopes. In these circumstances marked disparities in stream gradients between adjacent stream courses were common. In particular, those streams confined between end moraines such as to give them long circuitous courses tended to have low gradients. In contrast, those streams favorably located such that they followed a more direct route to the same destination tended to have higher gradients.

PHYSIOGRAPHIC SETTING

The physiographic setting of the area under discussion is shown in Figure 1. It encompasses parts of three physiographic districts, the

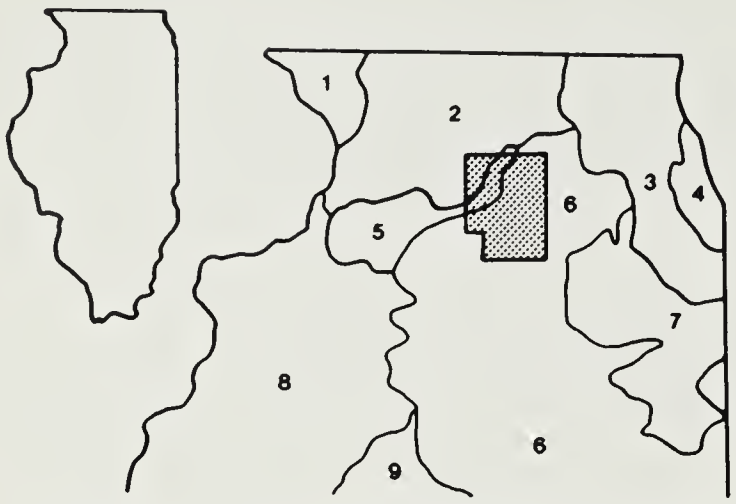

FIGURE 1. Location of study area (stippled). Numbers refer to physiographic districts. 1) Driftless Area; 2) Rock River Hill Country; 3) Wheaton Morainal Country; 4) Chicago Lake Plain; 5) Green River Lowland; 6) Bloomington Ridged Plain; 7) Kankakee Plain; 8) Galesburg Plain; 9) Springfield Plain.

Rock River Hill Country, the Green River Lowland, and the Bloomington Ridged Plain (Leighton, Ekblaw, and Horberg, 1948).

The Rock River Hill Country, which occupies a small portion of the northwestern part of the area, is characterized by low, hilly topography. In contrast to the Green River Lowland and the Bloomington Ridged Plain, glacial drift is thin and bedrock exposures are numerous. Drainage patterns tend to be dentritic, reflecting the erosional homogeneity of the bedrock. Within the study region, the lower course of Kyte River forms the principal drainage in the district. This portion of Kyte River is unique among streams in the Rock River Hill Country in that it flows almost completely on glacial drift. The situation which has led to this condition is the existence beneath the Kyte River of a buried preglacial valley (Horberg, 1950). Apparently Kyte River has been developed following the more easily erosible materials occupying this former valley, and some of its dynamic character can be attributed to this relationship.

The Green River Lowland occurs as a narrow belt of low relief topography to the southeast of the Rock River Hill Country. Most of the Green River Lowland is developed on glacial outwash, although locally bedrock highs protrude through the drift. None of the current streams, however, are controlled in position by the bedrock highs. The Green River Lowland is currently drained by two streams, Green River in the south, and the upper course of Kyte River in the north. The divide between the two is ill-defined.

The larger portion of the study area lies in the Bloomington Ridged Plain, a district which is characterized by broad, rolling morainic ridges with intervening wide stretches of relatively flat ground moraine and outwash plain. Three distinct end moraines occur in the study area portion of the district, the Bloomington, Arlington-Elburn, and Farm Ridge Moraines (Figure 2). The Bloomington Moraine is the largest of the three and forms the principal drainage divide in the region. Crest elevations on the Bloomington moraine generally exceed 950 feet and rise 250 to 300 feet above the Green River Lowland. The Arlington-Elburn Moraine lies to the southeast of the Bloomington Moraine, and, except at the center of the area where it locally overrides the back portion of the Bloomington moraine, is separated from it by a distinct ground moraine lowland. The highest portions of the Arlington-Elburn Moraine rise to elevations in excess of 950 feet, although its crest common-

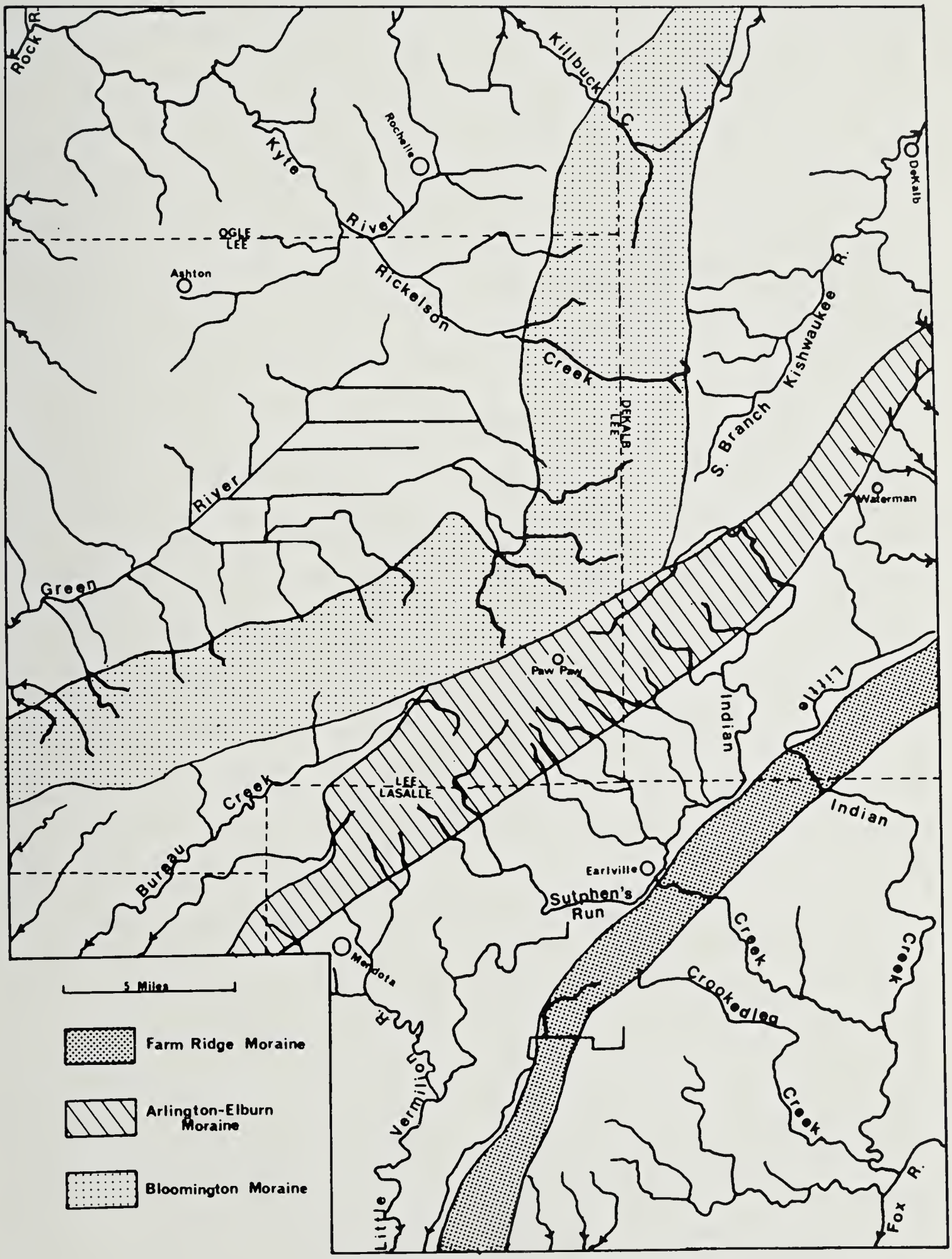

FIGURE 2. Present-day drainage system.

ly is less than 900 feet. The third moraine, the Farm Ridge, is the lowest and least distinct of the three, rising only 25 to 50 feet above the adjacent lowlands.

Each of the three moraines marks the outer limits of separate glacial ice advances into the region from the southeast. The limits of the moraines are mappable on the basis of their distinct till compositions. In age, the Bloomington Moraine is the oldest and the Farm Ridge Moraine the youngest. All three moraines are of Wisconsinan (Woodfordian) age.

There are four distinct lowlands separating the three moraines. Between the Bloomington and Arlington-Elburn Moraines are two lowlands separated by a high divide at the position of the overriding of the Arlington-Elburn Moraine on the Bloomington Moraine (Figure 2). To the north lies the DeKalb Basin, which is drained by South Branch of Kishwaukee River, and to the south lies the Bureau Creek Lowland, which is drained by Bureau Creek. The lowland separating the Arlington-Elburn and Farm Ridge Moraines is the Mendota Lowland. It is currently drained by portions of several drainage systems, the major streams of which are Little Vermilion River, Indian Creek, Little Indian Creek, Somonauk Creek, Big Rock Creek, and Little Rock Creek. The lowland to the southeast of the Farm Ridge moraine is the Fox River Lowland. It is drained by portions of the same drainage systems as the Mendota Lowland, with the exception of the Little Vermilion River system.

Relief in the lowland regions is very small. Values of 10 feet per square mile are not uncommon. Correspondingly, stream segments within the lowland regions tend to have very low gradients, and before settlement extensive swampy areas occurred in these lowlands. Currently, most of these swamps have been drained by the installation of field tile and the artificial entrenchment and straightening of the stream channels. As a result, all the lowland streams, although they continue to have low gradients, have higher gradients than in their original state.

Recognition of Stream Piracy

Several criteria allow the recognition of stream piracy. Foremost of these in the study area is the occurrence of drainage contrary to the region slope. Indian Creek (Figure 2) serves as an example. At two positions Indian Creek flows through moraines, the Farm Ridge and Arlington-Elburn, from the front side of the moraines to the back. In both cases the height of land occurs at the crest of the moraine and Indian Creek in its segments between the crest and the front of the moraine flows up the regional slope. Furthermore, in both cases Indian Creek diverges from lowlands in front of the moraines to pursue its course through the moraines.

Piracy can generally further be recognized if an "elbow of piracy" exists (Lander, 1968, p. 1055). Most commonly a pirating stream intercepts its competitor at right angles. After diversion occurs the point of interception is marked by a right angle bend in the new extended stream, termed the "elbow of piracy."

A third criterion is the presence of an abandoned valley segment crossing a narrow divide between streams (Thornbury, 1969, p. 149), particularly when it occurs in conjunction with an elbow of piracy. If the piracy has occurred recently such that post-piracy has not effaced the abandoned valley segment, this is the most convincing of the evidences for piracy. Fortunately in the study area most of the stream piracy has occurred sufficiently recently that abandoned valleys now forming divides are common.

Occasionally after piracy a small segment of the low gradient stream downstream from the point of interception will reverse its flow and join the drainage of the high gradient stream. In such a case the new divide between the pirating and pirated streams will be formed on the low gradient stream below the actual point of interception at the point where reversal of drainage occurred. Evidence of reversal of drainage is obtained where tributary streams join a main stream at an obtuse rather than the normal acute angle. This is referred to as "barbed drainage" (Thornbury, 1969, p. 120), and at least one good example occurs in the study area.

Indian Creek Piracy

Within the Bloomington Ridged Plain most of the major streams follow courses along the fronts of moraines. This is a relic condition dating from glacial times when the channels were originally formed by meltwaters gathering at the ice margin and flowing longitudinally along the moraine front. With the retreat of the glaciers, these channels remained to form the trunk streams of the post-glaciar drainage system.

Indian Creek and its principal tribuatry, Little Indian Creek, flow contrary to this pattern (Figure 2). Indian Creek rises in front of the Arlington-Elburn Moraine near the village of Paw Paw in eastern Lee County and flows northeastward along the front of the moraine in a normal position for six miles. South of Shabbona in DeKalb County, however, it executes a right angle bend and passes through the moraine in a valley as much as 60 feet deep. Once through the moraine it again makes a right angle bend and flows southwestward in an open valley, eventually crossing the ground moraine basin of the Mendota Lowland until it occupies a moraine front position along the Farm Ridge Moraine. At Earlville in La Salle County it once more makes a right angle bend and passes through the Farm Ridge Moraine in a narrow-walled valley 50 feet deep. Beyond the Farm Ridge Moraine, Indian Creek crosses the Fox River Lowland in a normal fashion until entering the Fox River at Wedron in La Salle County.

Little Indian Creek displays a similar anomaly in the regional drainage pattern by likewise crossing through a moraine. Little Indian Creek rises on the backside of the Arlington-Elburn Moraine southwest of Waterman in DeKalb County. From its head, it crosses the Mendota Lowland to occupy a normal moraine front position along the Farm Ridge Moraine. Northeast of Leland, however, it makes a right angle bend and passes through the

Farm Ridge Moraine. The two right angle bends of Indian Creek and the right angle bend of Little Indian Creek are elbows of piracy.

The anomalous cross - moraine drainage patterns of Indian and Little Indian Creeks are the result of three separate stream piracies (Figures 2-4), the sequence of which can be re-established on the basis of the topographic clarity of the piracy evidences. Initially, in immediate post-glacial times, the north-flowing South Branch of Kishwaukee River drained the bench region at the juncture of the Bloomington and Arlington-Elburn Moraines, and the long, narrow, moraine-confined Mendota Lowland was drained by an extended south-flowing Little Vermilion River (Figure 3). Gradients of both of these streams in their original state were probably very low. The drop in elevation along the extended South Branch of Kishwaukee River in a six-mile straight-line course from near Paw Paw to south of Shabbona was only 5 feet. The drop in elevation along the extended Little Vermilion River in the 16-mile straight-line distance from the head of the current Little Indian Creek to the divide between Sutphen's Run and the headwaters of the Little Vermilion system was 25 feet. Allowing for some irregularities in the channel courses due to meandering, as well as some recent downcutting, both of these streams therefore probably originally had gradients of less than one foot per mile.

The first piracy occurred when a tributary to the extended Little Vermilion River worked its way headward through the Arlington-Elburn Moraine south of Shabbona in De-Kalb County and intercepted the upper portion of South Branch of Kishwaukee River at position (1) on Figure 3. Reconstruction of the original slope on the backside of the Arlington-Elburn Moraine indicates that the headward advancing tributary had a gradient of approximately 40 feet per mile, contrasting sharply with the less than one foot per mile gradient of the South Branch of the Kishwaukee River. This diversion probably occurred shortly after the establishment of the original drainage, as the divide between Indian Creek and South Branch of Kishwaukee River at this point is currently 40 feet above Indian Creek, indicating an extended period of downcutting on the part of Indian Creek since diversion.

The second diversion occurred when Little Indian Creek eroded headward past the crest of the Farm Ridge Moraine and intercepted the Little Vermilion River at position (2) on Figure 3. The new divide was found immediately downstream on the pirated stream. It is currently marked by a broad mile-and-a-half long abandoned channel, the floor of which is 5 to 8 feet above the level of the present two streams.

The third diversion was the largest of the three. It occurred when the original Indian Creek cut headward through the Farm Ridge Moraine east of Earlville (position (3) on Figure 3) and captured approximately 110 square miles of drainage area which previously had been part of the extended Little Vermilion system. A conceptual view of this piracy is shown on Figure 4. Unlike the two earlier diversions, the divide between the pirating and pirated

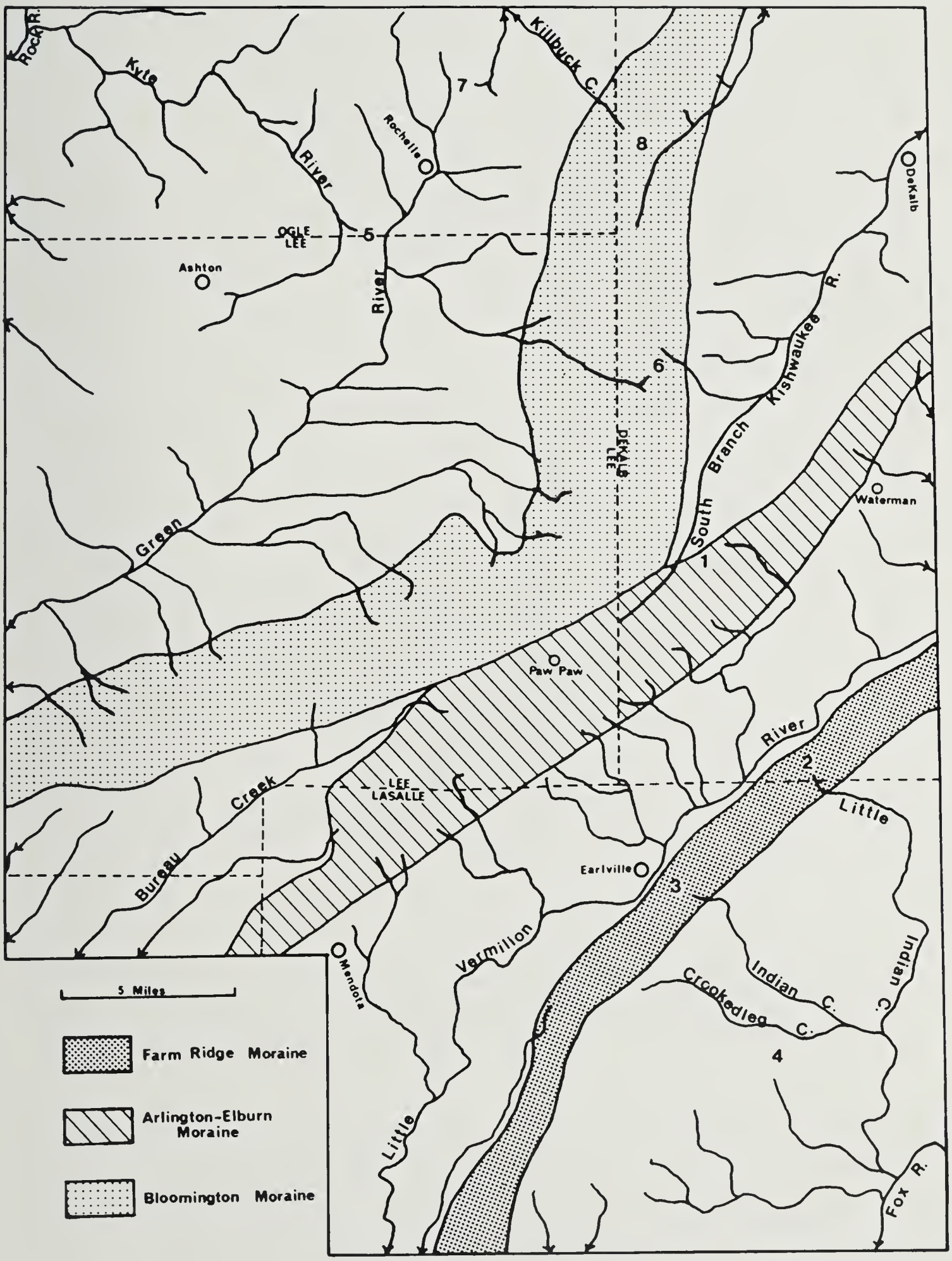

FIGURE 3. Reconstructed post-glacial drainage system.

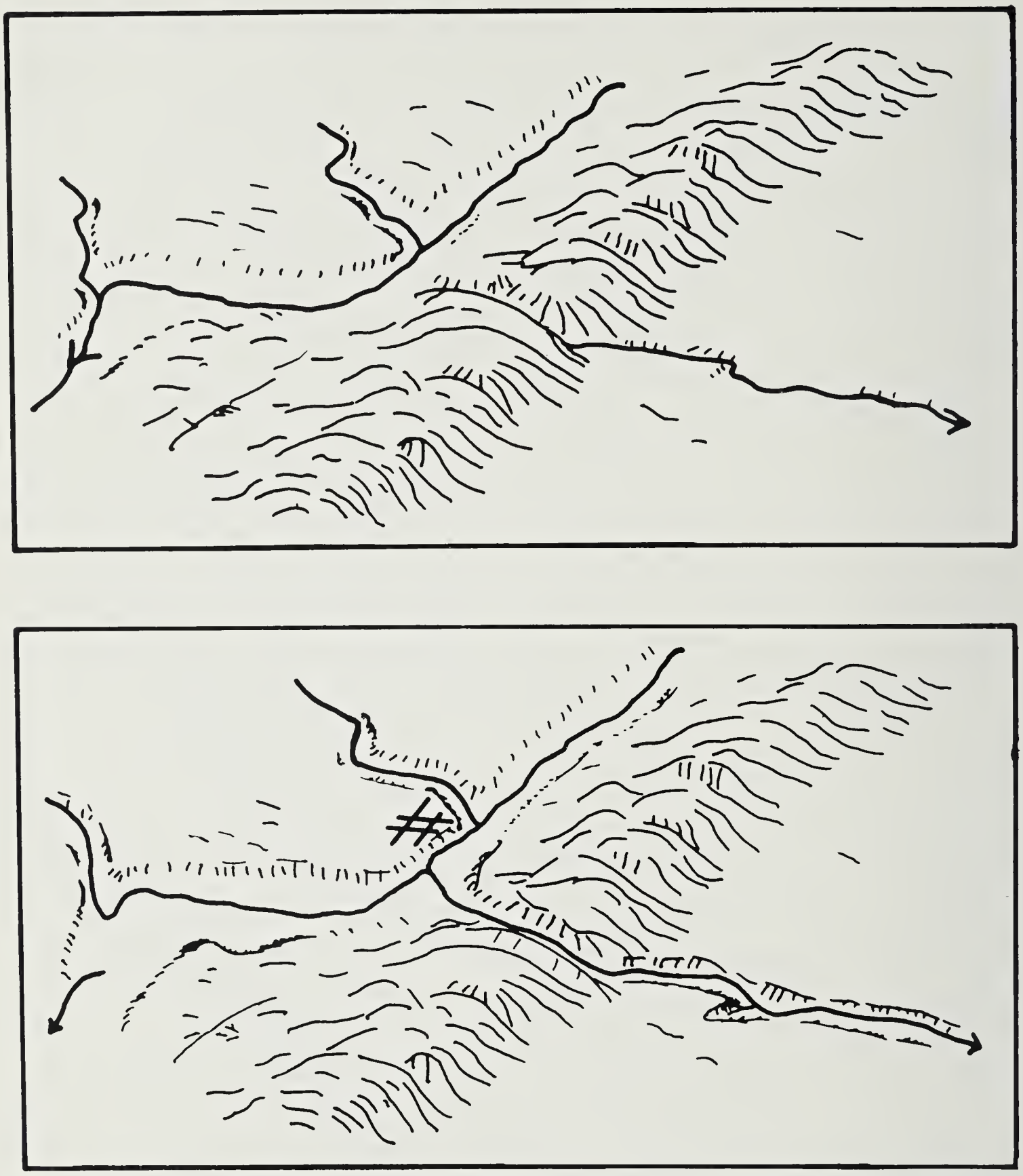

FIGURE 4. Progression of stream piracy at Earlville. Top: before piracy; bottom: after piracy.

streams did not develop at the point of interception. Rather, the divide formed downstream on the pirated stream, causing the intervening stretch of the river (Sutphen's Run) to reverse its flow. The recentness of this diversion is witnessed by the hairpin, barbed turn in Sutphen's Run and the freshness of the abandoned valley which forms the divide between Sutphen's Run and the headwaters of the Little Vermilion system. The highest portion of this divide is currently less than 5 feet above the level of the two streams.

At the present time the average

valley gradient, exclusive of streams meanders, along the Little Vermilion system from the divide south of Sutphen's Run to its mouth on the Illinois River is 9.6 feet per mile. This compares well with the average valley gradient of Indian Creek, which from the same divide to its mouth on the Fox River is 9.8 feet per mile, and suggests that equilibrium between the two competing systems has now been attained.

A fourth, and somewhat unusual case of stream piracy has recently occurred on a small tributary to Indian Creek, Crookedleg Creek. Crookedleg Creek formerly flowed into Indian Creek above its confluence with Little Indian Creek (Figure 3). Another tributary to Indian Creek has cut headward across the Fox River Lowland and diverted Crookedleg Creek two miles above its former mouth into a new channel to the south (Figure 2). A prominent abandoned valley connecting Crookedleg and Indian Creeks at the elbow of piracy marks the former course of Crookedleg Creek.

Kyte River Piracy

The majority of streams in the Rock River Hill Country district are cut into the thinly covered bedrock of the district. An exception occurs with Kyte River. In pre-glacial times an eastward flowing stream drained the region now drained by the westward flowing Kyte. This valley became blocked with glacial drift, probably during the early Wisconsinan ice advances. With the retreat of the ice, Kyte River became established into the soft glacial fill of the old valley, and rapidly extended itself headward toward the Green River Lowland. Currently the gradient of Kyte River in its segment within the Rock River Hill Country is 7.31 feet per mile.

The initial drainage in the Green River Lowland entered the Green River, which then extended northward beyond Rochelle (Figure 3). Green River originated during the Bloomington Glaciation when it served to transport meltwater longitudinally along the outwash plain which was developing in front of the Bloomington Moraine. Consequently then, as now, Green River had a low gradient. Since settlement most of Green River has been canalized and artificially straightened to assist drainage for agricultural purposes, and its present gradient is therefore steeper than in its natural state. Nevertheless, Green River still has an average gradient over its 115 straight-line course of less than 1.5 feet per mile.

The more dynamic Kyte River intercepted the Green River at a point south of Rochelle along the Lee-Ogle County Line, forming an elbow of piracy and diverting approximately 82 square miles of the headwaters of Green River. Both the height of this divide, which today is about ten feet above the two streams, and the rounding of the elbow of piracy, suggest that the diversion occurred fairly early in post-glacial times.

Other Piracy Cases

Several lesser cases of stream piracy also occur in the study area. These are represented by positions (6), (7), and (8) on Figure 3. At

position (6), Rickelson Creek, currently a tributary to Kyte River but formerly a tributary to Green River, has eroded headward through the Bloomington Moraine to capture several small eastward-flowing former tributaries to South Branch of Kishwaukee River. The headwaters of Rickelson Creek currently drain as much as 2 miles east from the crest axis of the Bloomington Moraine.

At position (7), a tributary to north-flowing Killbuck Creek has captured a part of the former southward-flowing Green River drainage, and at position (8), Killbuck Creek has captured a segment of Owen's Creek which formerly flowed through a low portion of the backside of the Bloomington Moraine. The divide between Killbuck and Owens Creeks is also marked by a low, abandoned valley.

Future Piracies

Barring man's intrevention, several additional cases of stream piracy are imminent in the study area. The foremost of these is the impending capture of the headwaters of Indian Creek northeast of Paw Paw by one or more of the tributaries to Indian Creek which drain directly off the back of the Arlington-Elburn Moraine (Figure 2). Currently two of these tributaries, which have gradients in excess of 100 feet per mile near their heads, approach within ½ mile of the main Indian Creek channel.

In the vicinity of Waterman and northeast (Figure 2), Somonauk, Little Rock, and Big Rock Creeks are currently extending themselves headward through the Arlington- Elburn Moraine and will eventually intercept and capture a portion of South Branch of Kishwaukee River. On the west side of the DeKalb Basin, Rickelson and Killbuck Creeks may also be expected to continue the attrition of the drainage of the Kishwaukee system as they erode headward through the Bloomington Moraine.

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FEEDING ACTIVITIES OF CANADA GEESE IN SOUTHERN ILLINOIS

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Abstract. — Feeding activity of Canada geese correlated with low light intensity being greatest during early morning, late afternoon, moonlight nights and the entire day if the sky was overcast. Observations in the Crab Orchard Refuge area during October-March showed cornfields to contain 41% of feeding geese, small grains 24%, pasture 22%, soybeans 9% and wheat stubble and lespedeza fields 4%. There was increased use of forage crops with an increase in the moisture on the foliage. With one exception, grazed wheat fields showed decreased yields of 54 to 79% due to reduction in culm density and height, spike and seed numbers and weight of above-ground parts. One field, which showed a 13% greater yield for grazed sites, exhibited increased floristic production attributable to improved soil conditions due to decomposing geese feces. Major foods utilized by Canada geese in the Horshoe Lake area were soybean, corn, Johnson grass, various aquatics and wheat.

In recent years, Canada geese, *Branta canadensis interior* Todd, which previously wintered as scattered flocks along the Mississippi River have been attracted to a series of refuges in southern Illinois. Waste grains from the fall harvests, as well as crops provided on refuges, comprise a large percentage of the food utilized by these geese. However, forage available in fields of small grains and pastures is also important. This paper reflects various aspects of the foods and feeding habits of the Canada goose in southern Illinois during fall and winter of 1953-55.

Canada geese begin to arrive at southern Illinois refuges around September 15 with a steady increase in numbers through November. In the fall of 1954, the peak concentration of geese at Crab Orchard National Wildlife Refuge occurred during the week ending November 19, with an estimated 47,000 Canada geese, 1,910 blue geese, *Chen caerulescens,* and 5,390 snow geese, *Chen hyperborea.* In 1953, the population at Crab Orchard Lake peaked at 40,000 geese. In late December or early January populations of Illinois refuges frequently decline as geese disperse southward as a result of shortages of food related largely to inclement weather. The northward migration of these birds begins in February and is completed early in March; hence, 5 to 6 months are spent in the southern Illinois region.

Feeding Activities at Crab Orchard National Wildlife Refuge

Studies of the feeding activities of Canada geese were made at the Crab Orchard National Wildlife Refuge during October through March of 1953-54 and 1954-55. During this period observations were made daily from before sunrise to shortly after sunset; some time was also spent in the field at night.

Feeding Flight—Feeding flights of geese appeared to be correlated with light intensity. Flights to fields began about sunrise and after 1 or 2 hours, the geese would return to resting and loafing sites on the refuge. When skies were overcast, morning flights were delayed 30 minutes to 1 hour. A second feeding flight began about 2 hours before sunset and the return to roosting sites occurred at dusk. When the sky was heavily overcast flight activity tended to be dispersed throughout the day. Some feeding flights also took place on bright moonlight nights.

Field Utilization — From October 1954 to March 1955, goose utilization of agricultural lands was determined by counting the number of geese observed along a census route which was driven biweekly between 8 and 9 a.m. Along this route, corn, soybean, small grain and fallow acreages were approximately equal; pasture was about twice that of other categories.

Corn fields contained 41 percent of the geese observed in the fields and hence, probably constituted the most important food item at Crab Orchard National Wildlife Refuge. One-third of the corn acreage was left standing by the private farmers as rent for the use of refuge land. Waste grain left by mechanical harvesters and ears of corn low enough to be reached on the standing stalks were consumed by the geese during the fall. During the winter the standing corn was knocked down by Refuge personnel so that geese would have easier access to this grain. This practice has been discontinued as it was determined that geese can utilize standing corn.

Fields of small grain yielded 24 percent of the geese recorded. Large open fields with little plant cover, such as fall-planted small grains or soybean stubble, were preferred by feeding geese in the early fall. As the number of geese increased during October and November, the wariness of the birds declined resulting in the utilization of pastures with tall, dense stands of forage; also, small-grain stubble with growths of weeds 3 to 4 feet high were utilized.

Pastures of timothy, redtop, bromegrass and bluegrass provided 22 percent of the feeding geese. Utilization of pastures increased as availability of corn, soybeans and small-grain forage declined.

Soybean fields harvested by mechanical pickers contained 9 percent of the feeding geese; heaviest usage was early in the fall, prior to the harvest of corn. Weed-infested wheat stubble and Korean lespedeza fields yielded 4 percent of the feeding geese. Adventitious wheat, cheat and broad-leaved weeds were the food items utilized.

A combination planting of wheat, barley, oats and rye was evaluated for grazing by geese. Based on time and intensity of grazing, the preferences by geese were in decreasing order: wheat, rye, barley and oats. The production of forage, which was primarily determined by rate of growth in the fall, was in decreasing order of bulk: rye, oats, barley and wheat. The recovery of the grazed stands in decreasing degree was rye, wheat, barley and oats. The grazed stands of barley and oats suffered severe frost damage because goose

grazing of foliage and erosion which exposed roots.

The utilization of forage seemed dependent upon the amount of moisture on the foliage (Fig. 1). Heavy dew, frost, light rain or light snow resulted in geese concentrating in pastures or small-grain fields rather than in corn or soybean fields. Helm (1951) reported a similar shift in field utilization under varying moisture conditions.

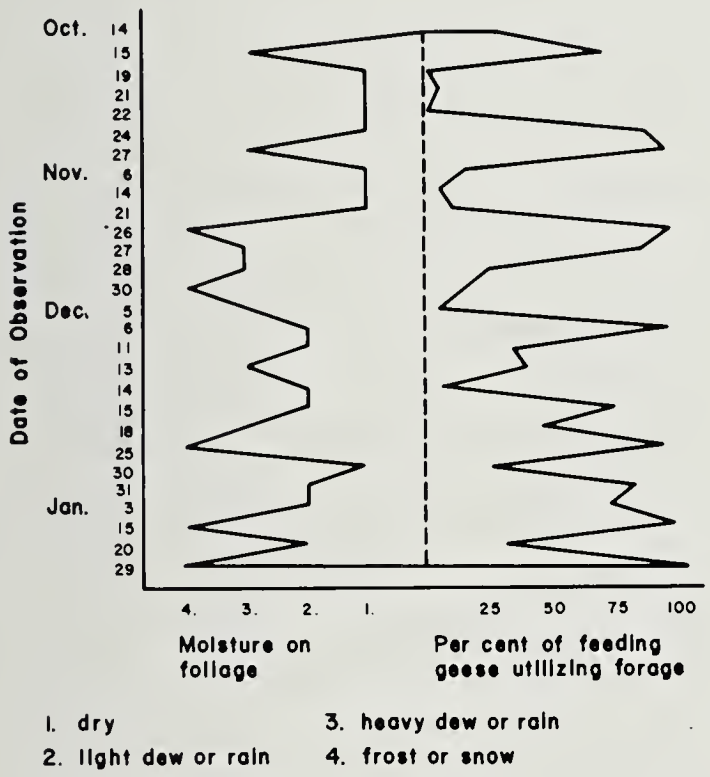
Oct. 14 15 19 21 22 24 27
Nov. 6 14 21 26 27 28 30
Dec. 5 6 11 13 14 15 18 25 30 31
Jan. 3 15 20 29
Date of Observation
4. 3. 2. 1.
Moisture on foliage
25 50 75 100
Per cent of feeding geese utilizing forage
1. dry
2. light dew or rain
3. heavy dew or rain
4. frost or snow

FIGURE 1. Relationship of goose utilization of forage with extent of moisture.

Effects of Geese Grazing Winter Wheat—During the fall of 1953, 11 wheat fields on or in the vicinity of Crab Orchard National Wildlife Refuge and 5 on the Union County Wildlife Refuge were selected for study. One or two exclosures, constructed of 1-inch mesh poultry netting and protecting an area of 36 square feet, were erected in each field. These provided ungrazed plots for comparison with the remainder of the fields which was available to geese. Four of the five study fields on the Union County Wildlife Refuge were not utilized by geese. In the fifth field grazing reduced seedling density to the extent that the field was disced and samples for productivity estimates were unavailable. Six of the 11 fields in the vicinity of Crab Orchard Lake were grazed by geese.

When the wheat in fields used by geese matured in June, 1954, five samples, each comprising an area of 2 square feet, were collected from each exclosure and from grazed sites in the field. The morphometric features of each sample including number, weight and height of culms; number, size, volume and weight of seeds; average length and number of roots; and average photosynthetic area of leaves were recorded. Data from Field VI were not used as rodents damaged the samples.

The topography of wheat fields was gently rolling with slopes of 2 to 4 percent which were subject to sheet and rill erosion; soybean debris gave some protection in Field I. Soil type included Hosmer Silt Loam in fields II-V and Stoy Silt Loam in Field I; both soils have impervious subsoils which permit little or no internal drainage. Characteristically the soils are low in calcium, phosphorus, potassium, nitrogen and organic matter except where improvements have been made. In all fields, wheat was seeded by drill during the week of October 12-19 following a previous crop of soybeans or red clover. Seeding depth varied from 1 to 3 inches, seeding densities from 149 to 225/sq. yd.

In 1953, October and November were drier than the 10-year average, receiving 0.92 and 2.23 inches of

TABLE 1. Morphometry and yield of wheat from ungrazed and grazed sites in five fields near Crab Orchard Lake, 1954.

Items	Fields										
	I		II		III		IV			V	
	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed 2% Slope	Grazed 4% Slope	Ungrazed	Grazed
Calculated yields (bu/ac)	18	5	37	17	30	11	39	11	8	30	34
Avg culms/sample	50.2	42.5	66.4	56.0	57.8	41.5	55.7	36.0	21.6	65.4	67.0
Avg culm height (in)	35	16	41	28	33	21	38	25	19	38	31
Avg no. spikes/sample	43.0	19.5	56.6	50.3	48.7	30.3	49.7	35.3	22.3	60.4	64.2
Avg wt of above-ground parts/sample (g)	105	53	152	97	132	64	84	43	23	148	108
Avg no. seeds/sample											
0-1mm dia	0	16	0	1	0	0	0	0	0	0	0
1-2mm dia	32	143	18	315	27	236	81	103	77	33	16
2-3mm dia	690	145	1,260	651	1,059	383	1,175	409	302	1,115	1,266
Avg seed wt/sample (g)	23	4	48	24	40	14	46	13	10	44	46
Avg net seed vol/sample (cm^2)	20	4	42	21	34	13	45	12	1	35	38
Avg photosynthetic area/sample (sq in)	340	159	237	140	.....	.....	508	.....	.....	696	409

precipitation, respectively. Following a dry hot summer, this resulted in low soil moisture and limited wheat growth from the time of germination until late November. During November, temperatures averaged 1.6 degrees lower than normal, further restricting fall growth of wheat. Mild weather and adequate precipitation favored good growth of wheat during the spring of 1954.

Pattern of Goose Utilization

Fields in the inviolate portion of Crab Orchard National Wildlife Refuge were utilized from October to March; the specific dates depended upon proximity to Crab Orchard Lake. Fields I, II, III and IV were approximately ½ mile from the lake and received the heaviest use during November and December; Field V was grazed primarily during February and early March. Hunters prevented geese from feeding in privately-owned fields until the waterfowl season closed in December. Following this date geese fed on farmlands bordering the Refuge with increasing frequency until late February, when the population declined as the northward migration got underway.

Generally, geese grazed first the crests and then the slopes, working from the center of a field toward the borders. Fecal-dropping density was not an accurate index of the extent of goose usage or amount of forage consumed because it also reflected the amount of time the geese spent loafing in the field. This time varied with the location of the field, being greatest in fields I and II and least in fields III, IV and V.

Yield of Wheat

In all fields except one, grazing by geese resulted in a 54 to 79 percent loss in yield of wheat (Table 1). Generally reductions in productivity could be associated with less weight of above ground parts (Fig. 2), decreased photosynthetic area (Fig. 3) and fewer spikes (Fig. 4).

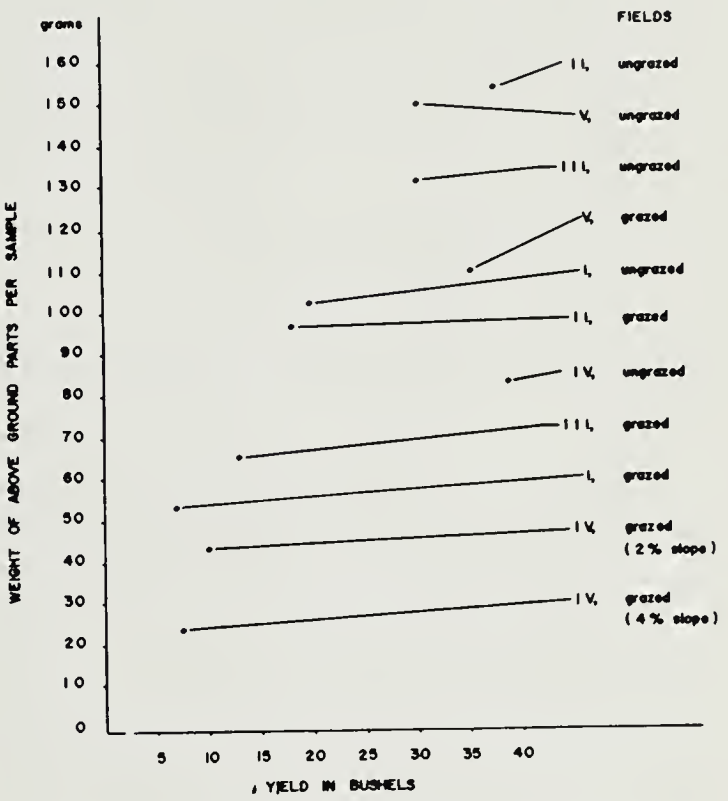

FIGURE 2. Relationship of weight of above ground parts per sample to yield of wheat.

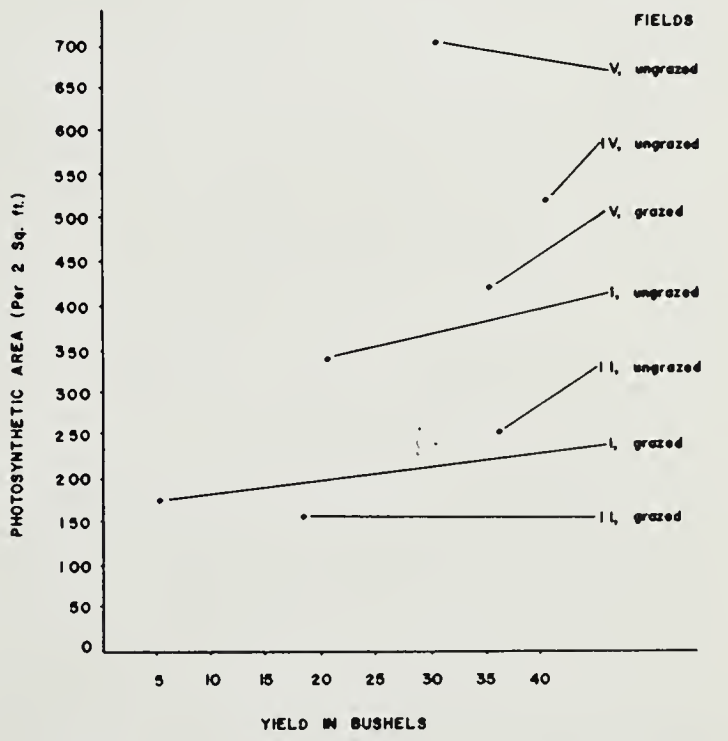

FIGURE 3. Relationship of photosynthetic area per sample to yield of wheat.

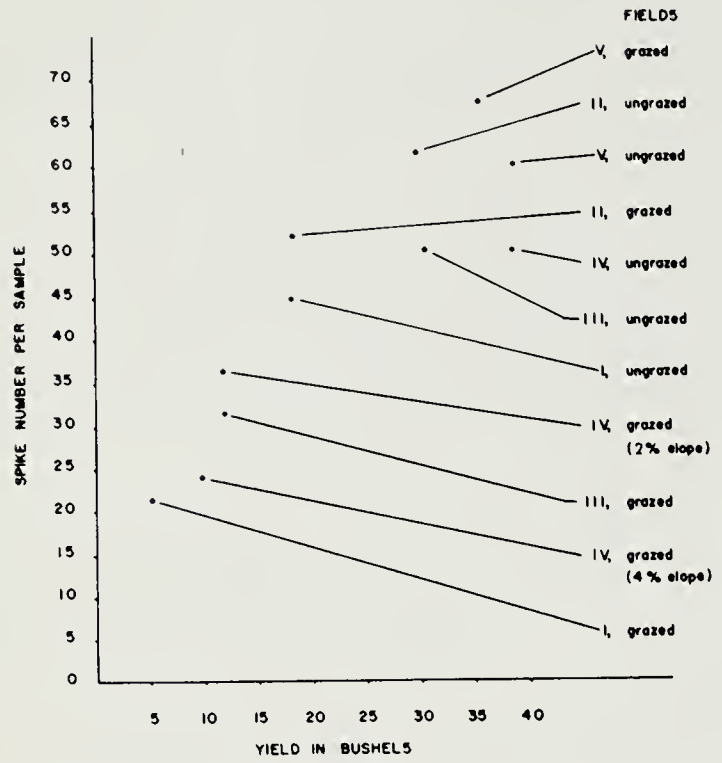

FIGURE 4. Relationship of average spike number per sample to yield of wheat.

Field V was distinctive in that yields from stands grazed by geese were 13 percent greater than the ungrazed stands (Table 1). In this field, wheat followed red clover, which left the soil higher in organic matter, moisture and nitrates than contributed by soybeans. Deeper drilling of the wheat further enhanced moisture conditions. The wheat responded to these favorable moisture conditions with rapid fall growth, producing a seedling which in March had three times the photosynthetic area and twice the tiller number of seedlings in any other field. Even after moderate grazing these seedlings still retained one-half the photosynthetic area of that of ungrazed seedlings in any of the other fields. This remaining foliage modified the adverse erosional effects associated with goose grazing. Also, Field V was exposed to erosion for a shorter period of time as it was grazed only in early spring; the wheat showed a rapid resumption of growth. An increase in soil fertility due to the deposition of goose feces was undetermined; however, the density of the feces was twice the average for other fields. Height, weight of above-ground parts and photosynthetic area were greater for samples from ungrazed sites than those grazed (Table 1); average culm number increased slightly on the latter site.

Previous reports on the effects of geese grazing small grains reflect no damage (Pirnie, 1954), serious damage (Atkeson and Givens, 1952; Biehn, 1951; Helm, 1951) and beneficial (Quinn, 1952; Washington State Game Department, 1953). Biehn (1951) reported that grazing by waterfowl, when the soil was not saturated, increased production of small grains by causing the formation of stools. In Field V culm densities and correspondingly, yields increased slightly as a result of grazing by geese; in the other fields these were depressed by grazing.

The direct effects of defoliation of the wheat seedling by geese varied widely with the time of grazing. Early fall grazing reduced potential fall growth, root development and food storage. This resulted in low resistance to frost damage during the winter, a slow resumption of growth in the spring, a decrease in culm density and cumulative growth and a drop in seed production. Late-winter or early-spring grazing did not materially restrict accumulation of food reserves in Field V as spring growth was not noticeably retarded. The over-wintering foliage apparently reached its peak photosynthetic activity during the fall, slowing with lower temperatures and frost injur-

ies during the winter, and being replaced early in the spring with new growth of leaves and an elongation of internodes. The value of the overwintered foliage to plants in the spring was dependent upon the amount of food reserves in rootstocks and roots. These food reserves determined the capability of plants to produce new spring growth; the smaller the food reserves the more dependent plants were upon photosynthesis in the old foliage to produce the new spring growth. Thus the size of seedlings seemed to determine the degree of injury resulting from defoliation by geese and the time of grazing became an indirect effect.

The time of grazing also determined the period grazed fields were exposed to accelerated erosion; unfortunately, quantitative data were not collected. Stall, et al. (1954) calculated the soil loss from 2 to 3 percent slopes with clean-tilled crops at 2 to 5 tons per acre annually for fields in the Crab Orchard Lake watershed. The insidious effects of erosion seemed aptly demonstrated on grazed sites in Field IV where a 2 percent steeper slope showed a 27 percent lower yield (Table 1).

In Field V yields increased 13 percent as a result of grazing by geese while culm densities increased only 2 percent (Table 1). Influential in this yield increase was the 6 percent increase in average number of spikes and the 12 percent increase in average seed number. This increase in floristic production was attributed to changes in soil fertility due to decomposing geese feces. Quinn (1952) reported that extensive use of wheat in winter months by geese improved the final yield through the addition of fertility to the soil by the droppings. Cited as an example were three comparable fields which had been subjected to varying intensities of grazing. The heavily-grazed field yielded 33 bushels per acre, the lightly-grazed 25 and the ungrazed 18.

That the deposition of fecal material did affect soil fertility was indicated by the average decrease in pH of 0.7 on grazed sites in fields I, II, III and IV. On the basis of calculations by Helm (1951), a density of 2 to 5 fecal droppings per square yard contributed 1 to 2 lb of nitrogen per acre. Potassium values increased slightly in fields III and IV but had such a high availability that small additions from goose droppings probably had little effect. Available phosphate also increased slightly in fields III and IV on sites grazed by geese and probably was the cause of increased floristic production on the grazed sites in Field V. Phosphate was probably the key nutrient in Field V; because phosphate availability was low, small additions possibly had far-reaching effects. Seemingly, additions of phosphates would have produced the higher-grain production despite the decrease in weight of vegetative parts.

Food Utilization at Horseshoe Lake

Specific foods utilized by Canada geese (Table 2) were determined from an examination of 561 "crops" collected during November and December of 1953 and 1954, at a goose-picking station near Horseshoe Lake Refuge. Thirty-four percent (142)

TABLE 2. Fall foods of Canada geese harvested in the vicinity of Horseshoe Lake State Game Refuge, 1953 and 1954.

Food Items	Periods of Crop Collection													
	Nov. 1 to Nov. 7 (11 Crops)		Nov. 8 to Nov. 14 (55 Crops)		Nov. 15 to Nov. 21 (70 Crops)		Nov. 22 to Nov. 28 (51 Crops)		Nov. 29 to Dec. 5 (152 Crops)		Dec. 6 to Dec. 15 (80 Crops)		Totals (419 Crops)	
	Percent Volume 55cc	Percent Frequency of Occurrence	Percent Volume 758cc	Percent Frequency of Occurrence	Percent Volume 1,103 cc	Percent Frequency of Occurrence	Percent Volume 974cc	Percent Frequency of Occurrence	Percent Volume 2,510 cc	Percent Frequency of Occurrence	Percent Volume 847cc	Percent Frequency of Occurrence	Percent Volume 6,247 cc	Percent Frequency of Occurrence
PLANT	100.0	100.0	98.2	100.0	98.3	100.0	97.2	100.0	92.2	100.0	95.4	100.0	96.1	100.0
Glycine max	92.7	50.0	86.0	48.3	45.3	37.8	31.2	41.9	21.0	31.6	13.8	7.1	34.5	29.6
Zea mays	7.3	50.0	10.1	24.1	3.6	13.3	8.6	19.4	32.9	40.8	61.8	30.0	25.6	29.6
Sorghum halepense	.....	.....	.....	.....	4.3	8.9	27.6	41.9	16.7	23.5	3.3	14.3	12.3	18.1
Polygonum pennsylvanicum	.....	.....	Trace	6.9	3.5	28.9	5.9	25.8	4.8	23.5	9.9	52.9	4.8	29.9
Taxodium distichum	.....	.....	.....	.....	13.2	3.3	1.9	3.2	1.0	1.0	.....	.....	3.0	1.8
Eleocharis acicularis	.....	.....	.....	.....	.....	.....	.....	.....	3.9	4.1	3.8	1.4	2.4	1.8
Lemna minor	.....	.....	0.4	6.9	5.4	15.6	6.9	19.4	0.7	3.1	.....	.....	2.1	6.5
Triticum aestivum	.....	.....	.....	.....	0.1	1.1	.....	.....	4.5	12.2	0.1	1.4	1.8	5.1
Eragrostic hypnoides	.....	.....	0.1	6.9	3.1	4.4	4.0	12.9	Trace	2.0	0.9	2.9	1.7	5.1
Cyperus erythrorhizos	.....	.....	.....	.....	4.6	6.7	4.9	6.5	.....	.....	.....	.....	1.5	1.8
Eleusine indica	.....	.....	.....	.....	4.2	8.9	2.3	3.2	0.2	3.1	.....	.....	1.2	2.9
Polygonum lapathifolium	.....	.....	.....	.....	.....	.....	.....	.....	2.9	3.1	.....	.....	1.2	1.1
Cyperus ferruginescens	.....	.....	.....	.....	3.6	6.7	.....	.....	0.7	3.1	.....	.....	0.9	2.2
Digitaria sanguinalis	.....	.....	0.9	17.2	1.8	1.1	2.3	16.5	0.1	1.0	.....	.....	0.9	3.3
Jussiaea diffusa	.....	.....	.....	.....	2.7	4.4	0.5	3.2	.....	.....	0.6	1.4	0.6	1.4

TABLE 2. — (Continued)

Food Items	Periods of Crop Collection													
	Nov. 1 to Nov. 7 (11 Crops)		Nov. 8 to Nov. 14 (55 Crops)		Nov. 15 to Nov. 21 (70 Crops)		Nov. 22 to Nov. 28 (51 Crops)		Nov. 29 to Dec. 5 (152 Crops)		Dec. 6 to Dec. 15 (80 Crops)		Totals (419 Crops)	
	Percent Volume 55cc	Percent Frequency of Occurrence	Percent Volume 758cc	Percent Frequency of Occurrence	Percent Volume 1,103 cc	Percent Frequency of Occurrence	Percent Volume 974cc	Percent Frequency of Occurrence	Percent Volume 2,510 cc	Percent Frequency of Occurrence	Percent Volume 847cc	Percent Frequency of Occurrence	Percent Volume 6,247 cc	Percent Frequency of Occurrence
Polygonum punctatum									0.9	7.1			0.4	2.5
Echinochloa crusgalli					1.4	2.2	0.3	3.2	0.2	1.0			0.4	1.4
Quercus palustris									0.2	1.0	1.2	2.9	0.6	1.1
Panicum dichotomiflorum			Trace	3.5	0.5	1.1							0.1	0.7
Spirogyra sp.			Trace	3.5	0.6	2.2							0.1	0.7
Celtis laevigata							0.8	3.2	Trace	2.0			0.1	1.1
Ambrosia trifida									0.2	2.0			0.1	0.7
Amaranthus retroflexus									1.3	2.0			Trace	11.6
Nyssa aquatica			0.1	3.5	0.1	1.1							Trace	0.7
Ambrosia elatior					0.2	1.1							Trace	0.4
Setaria lutescens			0.1	6.9					Trace	1.0			Trace	1.1
Bidens sp.					Trace	1.1							Trace	0.4
Lepidium virginicum									Trace	1.0			Trace	0.4
ANIMAL									0.2		Trace		0.1	0.6
UNDETERMINED			1.8	24.1	1.7	2.2	2.8	6.5	7.6	21.4	4.6	12.9	3.8	14.8

of the crops contained no food items; unidentifiable debris represented 3.8 percent of the total volume. Twenty-eight plants contributed 96.1 percent by volume and had a 100 percent frequency of occurrence whereas animal matter yielded 0.1 percent by volume and was recorded in 0.6 percent of the crops. The latter was represented by Gastropoda, Coleoptera, Orthoptera and Diplopoda; these did not appear in the diet until late November.

By volume 14 plant foods yielded approximately 94 percent of the diet (Table 2); agricultural crops (61.-9%) included soybeans (34.5%), corn (25.6%) and wheat (1.8%). The use of agricultural crops was generally in accordance with acreage availability (Illinois Cooperative Crop Reporting Service, 1953); as well as the timing of soybean and corn harvests and winter wheat growth. Fourteen weed species associated with agricutural lands contributed 23.1 percent of the diet; Johnson grass (12.3%), a troublesome grass in the intertilled crops, was especially prominent. Several items of relatively minor volume, such as cypress, duckweed, rushes and sedges, reflected utilization of Horseshoe Lake.

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UPPER CAMBRIAN MAYNARDVILLE FORMATION WITHIN THE CLINCHPORT FAULT BELT OF EAST TENNESSEE

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Abstract. — First defined by Oder (1934), the relationships of this formation have been a subject of controversy. The source of controversy is the transitional nature of the Maynardville, which exhibits attributes of both the Conasauga Group (containing limestones) below and of the Knox Group (containing dolomite, stromatolites, chert, and oolites) above. Although there is a definite change of lithology from the Nolichucky Shale, the basal Maynardville boundary is gradational and shales are interbedded with limestones. The upper Maynardville boundary is even less well defined, being determined by the relative abundance of lithologic criteria.

Sixteen stratigraphic sections were measured along a 70 mile segment of the Clinchport fault belt in Tennessee. The Maynardville Formation can be divided into several persistent parastratigraphic units within the area of study. In ascending stratigraphic order, these units are: (1) ribboned-mottled unit, (2) intermediate limestone unit, (3) laminated unit, and (4) massive, thickly bedded dolomite unit. The Maynardville Formation is a mappable unit, but lithologically transitional between the Nolichucky Shale and the overlying Copper Ridge Dolomite. Furthermore, all four units have conclusive evidence of supratidal to intratidal origin of dolomite and limestone, respectively.

Since 1934 when C. R. L. Oder first defined the Maynardville Formation, it has been the subject of considerable controversy.

Albeit its age (Croixan) has never been seriously disputed, it has yet to be generally resolved whether the Maynardville deserves formational status and whether it should be included within the alternate shales and carbonates of the Conasauga Group or within the overlying limestones and dolomites of the Knox Group.

A review of the literature (Figure 1) has helped to point out the following problems concerning the Maynardville Formation: (1) placement of the lower formational boundary; (2) placement of the upper formational boundary; (3) traceability and/or mappability of lithologic units; and (4) interpretation of depositional environment.

Area of Study

Structually, the Valley and Ridge Province of East Tennessee is characterized by great northeast-trending thrust faults, which cause repetition of predominantly Cambro-Ordovician strata.

The outcrop belt known as the Clinchport fault belt (formerly known as the Hunter Valley fault belt) is bounded by the copper Creek fault on the southeast, and the Clinchport fault on the northwest. Figure 2 shows the area of study, adjacent strike belts, and location of measured sections. The area studied extends approximately 70 miles along strike from the northwest slope of Big Ridge near the Virginia-Tennessee state line to the Ralph Rogers quarry in Union Valley, two miles due east of Oak Ridge.

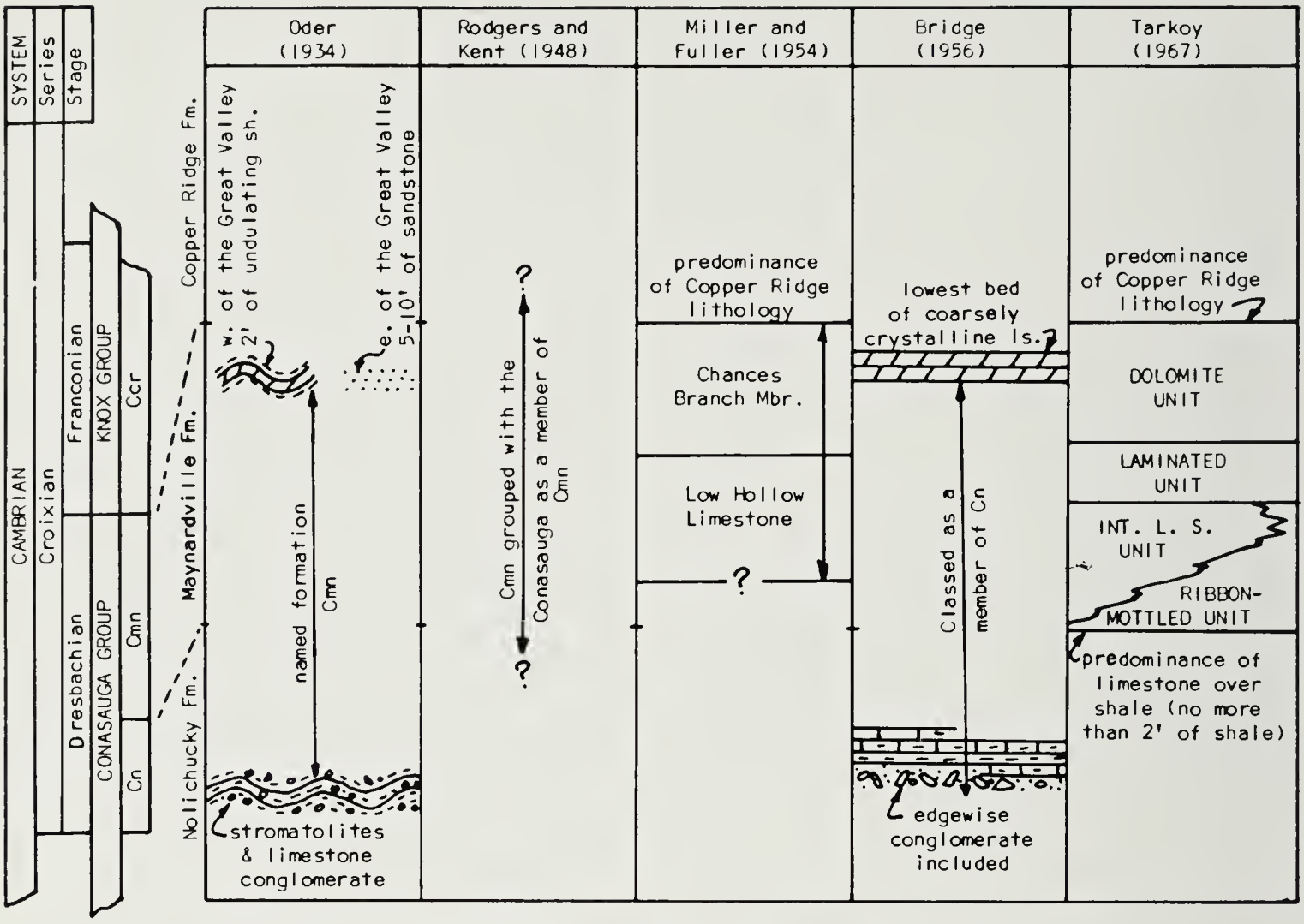


FIGURE 1.—Previous investigations, age, and correlation.

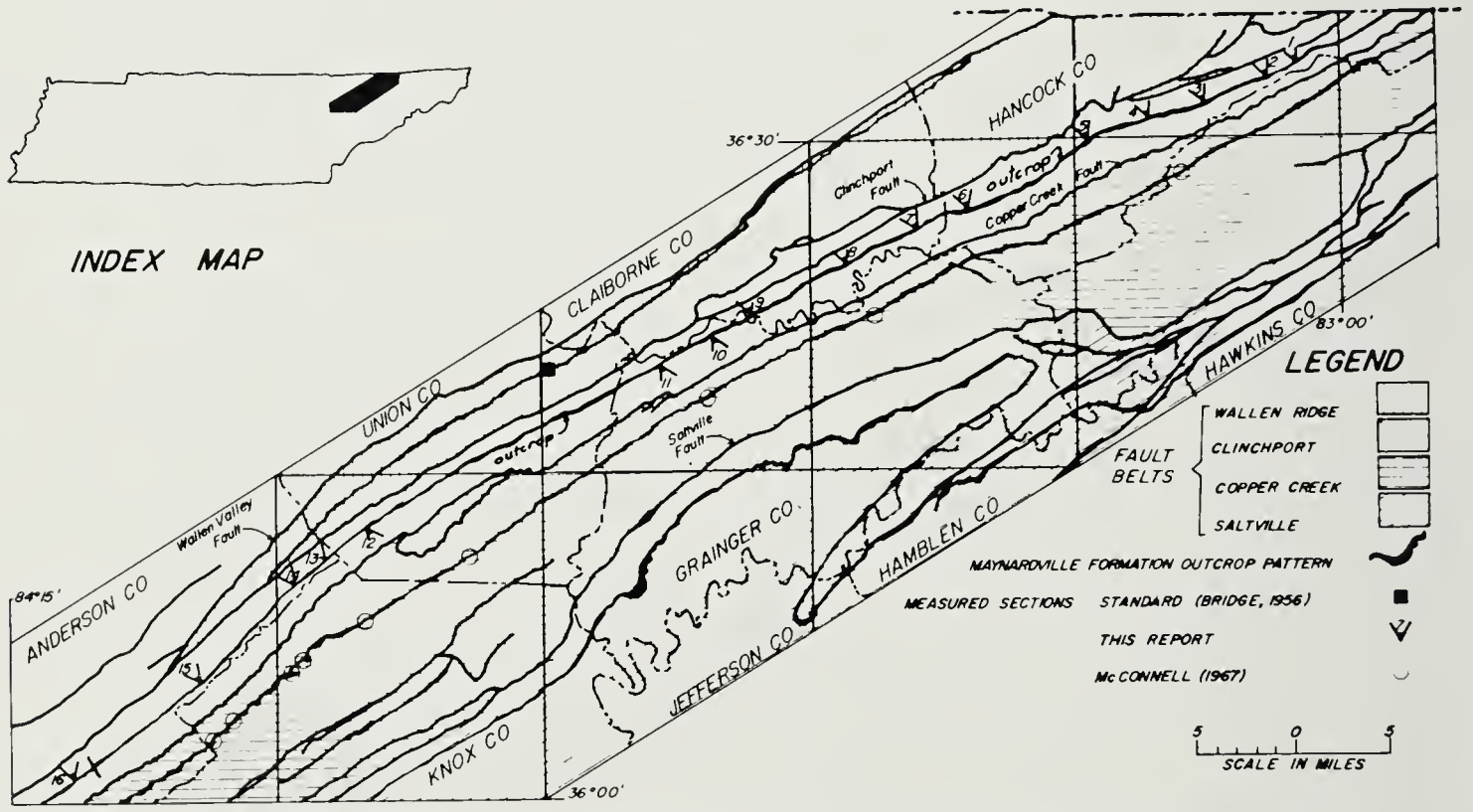


FIGURE 2.—Location of area of study, measured sections, and adjacent strike belts.

Age and Correlation

Although the Maynardville Formation and the underlying Nolichucky Shale are not highly fossiliferous, biostratigraphic studies have been successful in establishing their ages in the geologic time scale, as shown in Figure 1.

The lowest portion of the Upper Cambrian is the Dresbachian Stage, which is divided from the base upward into the *Cedaria, Crepicephalus,* and *Aphelaspis* faunal zones.

Upon modification of Raymond's (1959, p. 3) measured section, to confrom to the formation boundary criteria used in this report, it is noted that only the *Aphelaspis,* and no part of the *Crepicephalus,* zone is represented in the Maynardville Formation. Furthermore, Derby (1966, p. 43) similarly excludes all *Crepicephalus* fauna from the Maynardville Formation but he emphasizes that:

> . . . the base of the Maynardville is not everywhere the same age, nor is recognition of the *Aphelaspis* fauna necessary to identify the Maynardville Limestone.

Both Raymond (1959, p. 40) and Derby (1966, p. 41) have pointed out that, in the strike belts west of the Saltville fault, the base of the Maynardville is diachronous and progressively younger to the northeast, at least in Tennessee.

Lithostratigraphy

In this report the Maynardville is accepted as having formational status (as named by Oder, 1934). A summary of the field data is represented in Figure 3 in the form of

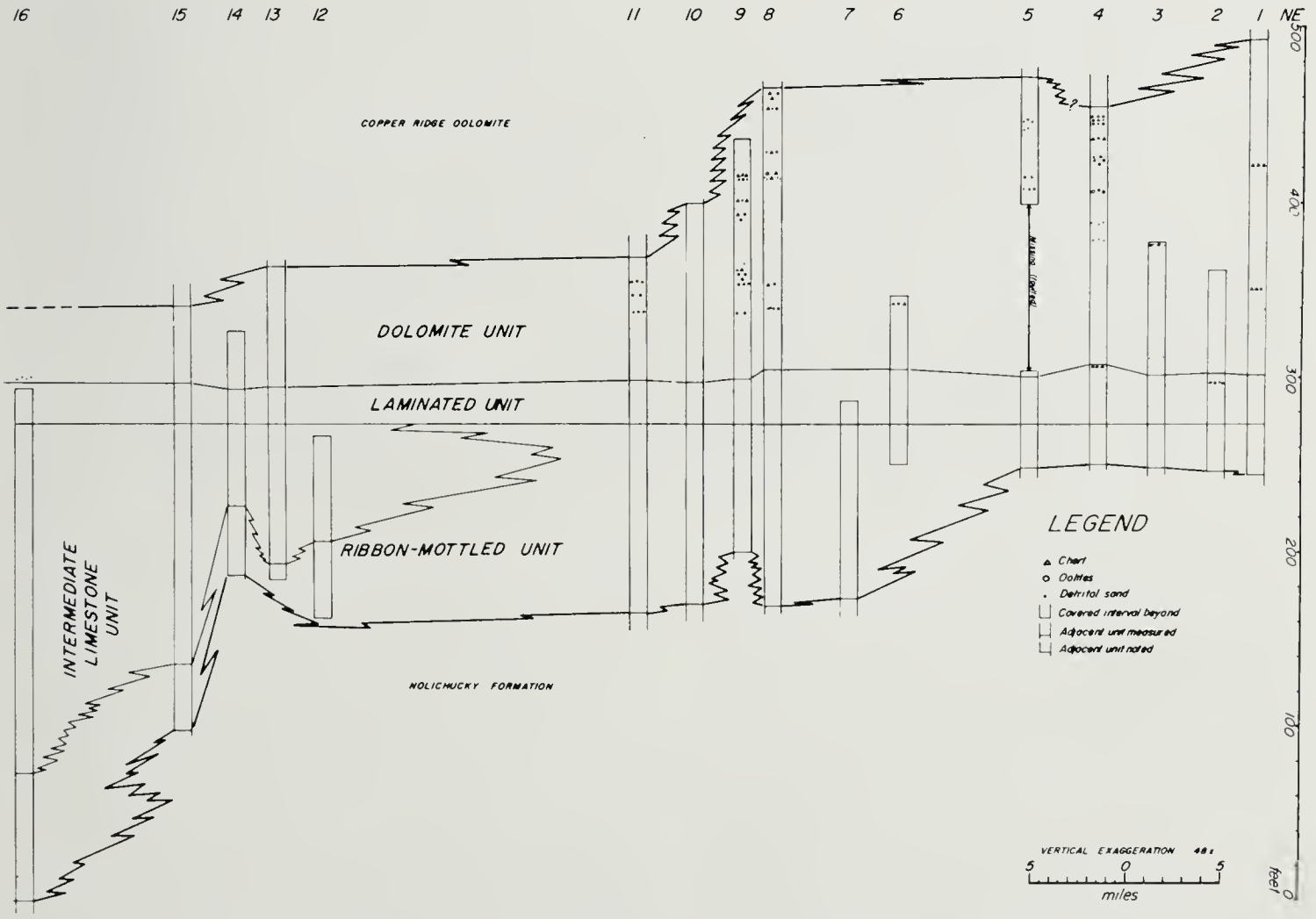


FIGURE 3.—Columnar sections and interpretation of stratigraphic data.

columnar sections of the Maynardville Formation as divided into parastratigraphic units. Detailed measured sections are reported by Tarkoy (1967). In the area of study the formation is divisible from the base upward into four parastratigraphic units which are: (1) a unit of ribboned and/or mottled limestone, (2) an intermediate limestone unit, (3) a unit of laminated limestone and/or dolomite, and (4) a dolomite unit containing within it two oolitic horizons, less continuous detrital sands, and stromatolitic zones which are not traceable along strike nor are they sufficiently fixed stratigraphically to be of any known significance.

Lower Formational Boundary. — The Nolichucky-Maynardville contact is intercalated and gradational within the area of study so that the uppermost portion of the Nolichucky Shale is characterized in places by large quantities of light olive gray shale, calcitic in part, interbedded with limestone similar to the superadjacent ribbon-mottled unit. This contact relationship can best be observed at section 4 and section 5 and other localities where the top of the Nolichucky Shale is sufficiently exposed. However, since the limestone interbedded with shale is discontinuous along strike, the contact is more abrubt in places.

Therefore, within this report, the lower formational boundary of the Maynardville is considered as occurring at the base of the first appearance of ribboned or mottled limestone with no more than two continuous feet of olive-gray shale above the contact. This criterion has the following advantages: (1) the limestone without interbedded shale is more continuous, better exposed, and useful for traceability in mapping and (2) the ribbon-mottled unit represents a substantial environmental change from that characteristic of the Nolichucky.

Ribbon-Mottled (limestone and dolomite) Unit. — The ribbon-mottled unit at the base of the formation consists of 20-100 feet of medium to very thickly-bedded, rarely thinly-bedded, medium-gray micrite, some of which is dolomitized. The beds are wavy; they are 0.25 to 1.5 inches thick and are separated by argillaceous limestone layers which range in thickness from mere films to beds an inch thick.

Intraformational conglomerates having intraclasts of 0.5 mm to 60 mm length are common at the base. Occasional pellets were noted, although the measured size of the intraclasts rarely exceeded 0.5 mm. Dark gray to light olive-gray calcitic shale (but not as olive as the shale of the Nolichucky) is present in the lower portion of the ribbon-mottled unit, in intervals averaging about one foot thick. These shales are more conspicuous to the northeast. Cyclical repetition of micrite and intramicrudite with thinly liminated calcitic shale was noted in the southwestern portion of the belt, notably at section 15 and at section 12. Oscillation ripple marks and mud cracks have been noted on bedding surfaces.

Suggestions of algal heads appear rarely except associated with transition to the intermediate limestone unit, a facies of the ribbon-mottled unit, appearing in the southwest portion of the study area. Although fos-

sils have been reported from the ribbon-mottled unit, only fossil fragments found were associated with intraformational conglomerates.

The dark yellowish-orange color of the mottled limestone results from the weathering of argillaceous or silty limestone bands. However, the ribboned appearance becomes apparent in more advanced stages of weathering (Figure 4A). If the limestone bands are silty, they are resistant and weather in raised relief, but if the limestone bands are argillaceous, the situation is reversed and weather to reentrants.

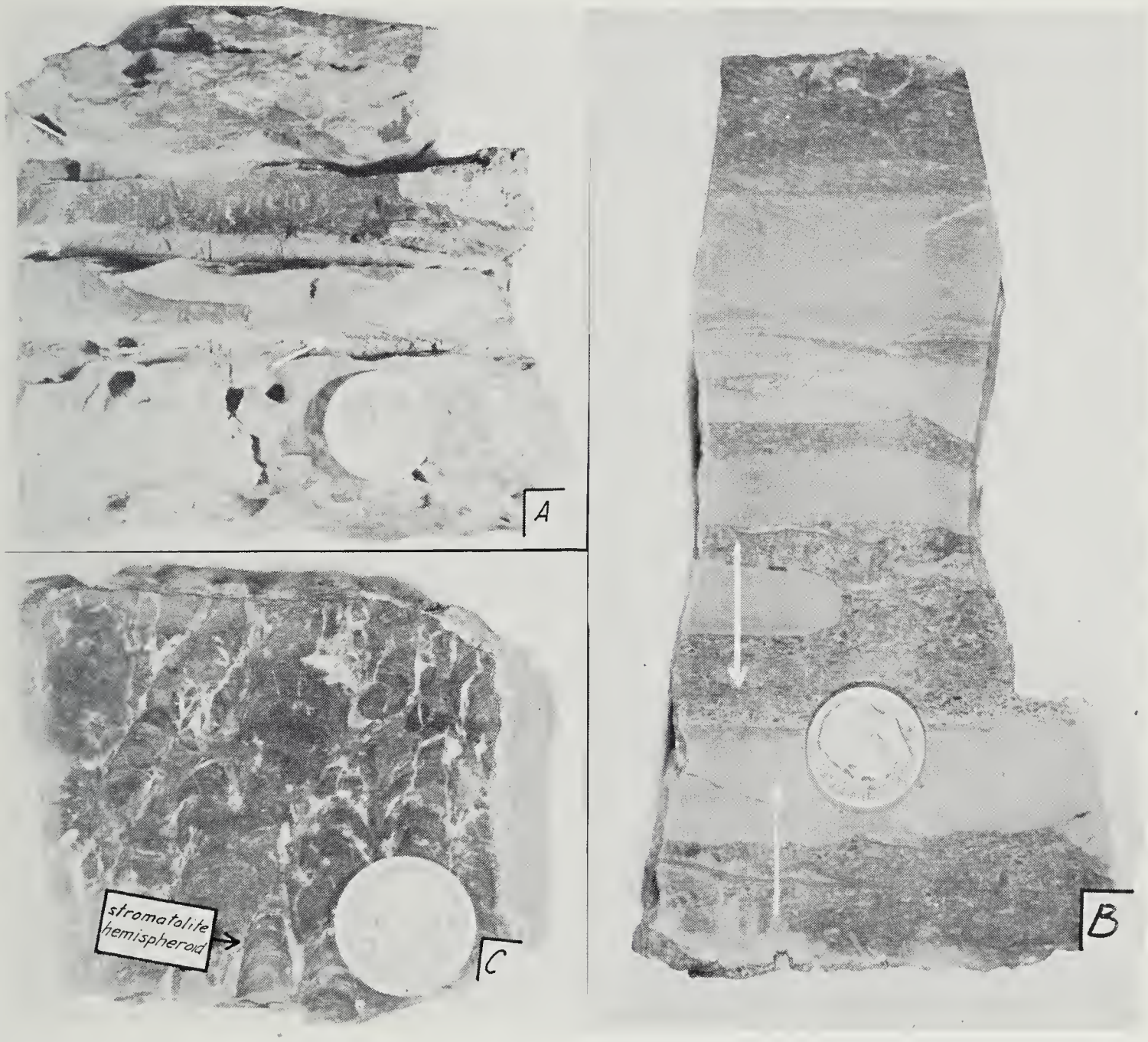


FIGURE 4.—A. This sample was collected from the ribbon-mottled unit at section 8. The bands weathering in raised relief are limestone and those weathering recessed (arrows) are argillaceous. The most significant process in the weathering of the argillaceous bands is hydration and swelling of the clays.

B. This sample was collected from the dolomite unit at section 8. It illustrates the widely variable size of the intraclasts, 0.5 mm to 15 mm (arrows). Such intramicrudites are found throughout the Maynardville Formation but they are most common in the dolomite unit.

C. This sample collected from the dolomite unit at section 4 illustrates closely stacked hemispheroid (SH type) stromatolites. Light areas are recrystallized dolomite; the specimen is predominantly dolomite. The dark color is a result of argillaceous material. The hemispheroids may be partly silicified (arrow) or completely chertified, as on the underside (not visible) of the sample.

The argillaceous or silty bands are almost always dolomitized, the dolomite being early or late diagenetic. Evidence of this diagenetic origin is shown by dolomite transecting bedding laminations.

The ribbon-mottled unit is the most persistent unit of the Maynardville, normally cropping out at the base of a series of locally named ridges, except in the southwestern third of the area of study, where the lower portion of the unit is in the valley floor and not exposed.

Intermediate Limestone Unit. — The intermediate limestone unit, being extremely and abruptly variable laterally, consists of 0-200 feet of massive stromatolitic limestone. It is a facies of the upper portion of the ribbon-mottled unit into which it grades northeastward along strike as well as locally in exposures. The unit is almost invariably very thickly bedded and massive, characteristically but not universally coarsely crystalline, medium gray to brownish dark gray, intraclast-bearing and abundantly stromatolitic.

Where the intermediate limestone unit is extremely stromatolitic, it weathers vuggy to ribboned and locally it intertongues with and grades into mottled limestone. The intermediate limestone becomes prominent from section 12 southward and attains its greatest thickness at section 16.

The unit is well exposed beneath the laminated unit in sections 13 through 16 (Figure 3).

Laminated (limestone and dolomite) Unit. — The laminated limestone and dolomite unit is composed of 20-30 feet of limestone grading into and interbedded with dolomite; however, the laminated character is constant and distinct. The unit has a variable argillaceous content (up to about 40 percent insoluble residues) and is characterized by the alternation of light laminae with dark limonitic, argillaceous laminae on the order of 10-25 per inch in section. The dark argillaceous laminae may be dolomitized at the base in a transitional zone from the ribbon-mottled unit. The unit is medium-bedded unless extremely weathered; in which case the finely laminated rock weathers shaly (as in section 6). The limestone and/or dolomite is finely crystalline, very light gray to brownish medium gray and weathers light to medium-gray.

Penecontemporaneous deformation is represented by microfolds and faults; stylolitic solution is common as in sections 2 and 4; intraformational conglomerates have been noted in section 11. Chert is found this low in the section but only in the northeast (section 2). Mud cracks have been noted on bedding surfaces.

The unit seems to be barren of fossils except for stromatolites in places. The peculiar laminar aspect of the unit may represent cycles of carbonate muds and argillaceous material cemented by algal films.

A noteworthy feature of the laminated unit is that nowhere is it interbedded with underlying or overlying units; therefore, it is not a lateral facies. The unit is unique in this respect; the sudden and areally extensive episodic appearance of short-lasting tidal flat conditions is considered to be a synchronous event, especially at the base of the unit where this change is extremely well-defined. Because of the greater con-

tinuity of the Chances Branch Dolomite, Harris (1964, p. B28) used it as a time reference surface datum in more extensive regional studies to show the northwestward transgression and facies relationships of the Rome Formation and Conasauga Group.

In many places the laminated unit weathers shaly and outcrops are poorly exposed.

Dolomite Unit.—The dolomite unit consists of 50-200 feet of dolomicrite, dolomicrudite, biolithite, and minor occurrences of other lithologies, attaining the greatest thickness to the northeast. Although the unit is usually very poorly exposed to the southwest, it thins to approximately 50-60 feet as seen in the quarry along (Copper Creek strike belt) U. S. Highway 70 (0.4 miles east of New Midway Church, Roane County, Cave Creek quadrangle). It is thinly-to thickly-bedded, and bedding may be undulatory; finely to coarsely crystalline; light gray to brownish black. McConnell (1967, p. 21) described the lower portion of the unit separately as a banded dolomite unit (in the Copper Creek outcrop belt). In the (Clinchport belt) present study area, the writer feels that this division is unjustified because: (1) the lower and upper limits of the banded dolomite are too vague and nondescript in outcrop and (2) the lithologic criteria for this distinction is laterally discontinuous.

Locally there is extensive evidence of penecontemporaneous deformation and intraformational conglomerates (Figure 4B). Stromatolites (Figure 4C) and chert (dark gray to black, lenticular or cross cutting bedding) are notable throughout the unit; however, they are more abundant at the top where the contact with the stromatolitic, oolitic, and cherty Copper Ridge Dolomite is gradational. The chert is generally related to the stromatolitic material which is commonly silicified. Locally, especially where the dolomite is stromatolitic, sparry and large crystalline (2cm) calcite fills vugs.

Where stromatolites are abundant the dolomite weathers to massive vuggy beds. The dolomite unit weathers readily to an orangish-yellow soil; therefore, good outcrops are rare.

Within the dolomite unit there are two oolitic zones (Figure 3). Detrital lenticular sands occur within the unit at various seemingly unrelated, stratigraphic horizons.

Upper Formational Boundary.—The transitional nature of the Maynardville Formation makes the selection of an upper formational boundary somewhat difficult. Oder's (1934, p. 475) original sandstone criterion is not applicable on the west side of the Valley and the two feet of dark gray-shaly dolomite, with an undulating upper contact has been discredited by Bridge (1965, p. 13).

The base of the Copper Ridge Dolomite has been placed by various authors at (1) the lowest bed of dark, coarsely crystalline dolomite (Bridge, 1956, p. 13), (2) at a point of relative dominance of the Copper Ridge and Maynardville type lithologies (Miller and Fuller, 1954, p. 38) and (3) at the base of the first appearance of typically Copper Ridge chert (McConnell, 1967, p. 30).

Chert (section 2) and stromatolites (in the ribbon-mottled unit in

the southwest portion of the study area) occur low in the section; therefore, a mere presence of either of these features is not sufficient, contrary to the usage by Bridge (1956, p. 13) and McConnell (1967, p. 30).

Ideally, regardless of the criteria used, they should be applicable over the areal extent of the formation and they should be useful on good exposures as well as poorly exposed or covered intervals. However, since the Maynardville is such a highly variable unit, the usefulness of the criterion followed in this report is probably restricted to the three western belts in northeastern Tennessee. In this report, the base of the Copper Ridge Dolomite is accepted as being at the

> . . . place where the dark-gray crystalline dolomite (characteristic of the lower Copper Ridge Dolomite) exceeds in relative abundance the light-gray, fine-grained dolomite of Chances Branch Member type. (Miller and Fuller, 1954, p. 38)

The advantage of the criterion is that: (1) the boundary can be chosen fairly easily in outcrop, (2) the gradational nature of this upper formational boundary indicates a slowly changing environment which is areally extensive, and (3) the abundance of chert in extremely weathered intervals is correlative with the abundance of stromatolites (perhaps the source of dispersed silica) and chert may even replace stromatolitic structures.

It must be emphasized that a transitional unit cannot by its own definition have sharply defined boundaries.

Petrography

All collected lithologic samples (150) were polished, classified according to Folk's (1962) spectral subdivision of limestone types, and located and described in each measured section (Tarkoy, 1967). In addition, 25 thin sections were cut from samples taken for each parastratigraphic unit at several localities in the Clinchport strike belt.

Qualitative mineralogical differentiation was facilitated by etching with dilute hydrochloric acid (10 per cent), and staining with inorganic dyes as described by Freidman (1959, pp. 87-97).

For purposes of description and summary, each parastratigraphic unit is divided into microfacies representing the most characteristic and persistent lithologies, summarized, and presented in Figure 5 and illustrated in Figure 6.

Conclusions

Interpretation of Stratigraphic Data.—The vertical succession of parastratigraphic units is homotaxial at all sections studied, but they do not maintain constant thickness. Figure 3 illustrates the relationship of the northward thinning of the limestone and the southward thinning of the dolomite. This is in agreement with Harris (1964, p. B28) who reports the limestone thins northwestward and is missing in Bell County, Kentucky.

McConnell (1967, p. 9) uses the chert and oolite horizons as time lines. In the writer's opinion there is not enough evidence in the Clinchport or Copper Ridge strike belts to support this assumption, especially

Unit	MICROFACIES & CLASSIFICATION	GRAIN SIZE AND DESCRIPTION
DOLOMITE	12-BIOLITHITE (Fig. 6H)	1.0mm, calcitic or dolomitic, silty, pelletoidal, silicified; mud flat environment
	11-DOLOMICRITE (Fig. 6G)	.005-.02mm, contains detrital sand & oolites; diagenetic
	10-CHERT	Chalcedony & opaline material, occasional silicified oolites & fossil fragments
	9-OOLITES (Fig. 6F)	.05mm, inconspicuous unless opaline; tidal
	8-DETRITAL SAND (Fig. 6E)	.3mm, quartz feldspar; dolomicrite pellets, .2-0.5mm
LAMINATED	7-DOLOMICRITE (Fig. 6D)	.01-.05mm, alt. laminae; dolomitized micrite has higher argillaceous content; desiccation features
	6-MICRITE	
	5-TRANSITIONAL (Fig. 6C)	Similar to 1 & 2 but finer laminae
INTER-MEDIATE LIMESTONE	4-BIOLITHITE	Similar to microfacies 12; mud flat environment
	3-INTRAMICRITE (Fig. 6B)	.01mm, mud; .01-1.0mm, recrystallized calcitice; 03-5.0mm, intraclasts; high energy shallow water
RIBBON-MOTTLED	2-DOLOMITIZED MICRITE	.01-.05mm, argillaceous & silty; diagenetic dolomitization may transect bedding
	1-MICRITE (Fig. 6A)	.02mm, mud cracks; direct precipitation, trace of recrystallization, mud cracks, shallow water

FIGURE 5. — Microfacies, classification and description.

since the oolites zones are lenticular and they cannot be traced unless they are silicified. Although there is a minor amount of chert in the Maynardville, enough is present in the Clinchport fault belt both above and below the dubious "chert horizon" of McConnell that a definite correlation is questioned. The chert is secondary and generally associated with the stromatolites and quite unlikely to represent a synchronous surface especially if the "bedded" chert is discontinuous.

The frequent occurrence of stylolites throughout the formation and their intense development indicate that there may be considerable stratigraphic thickness missing by intrastratal solution, which may account for minor correlation difficulties.

Interpretation of Depositional Environment.—Mud cracks are present in each of the parastratigraphic

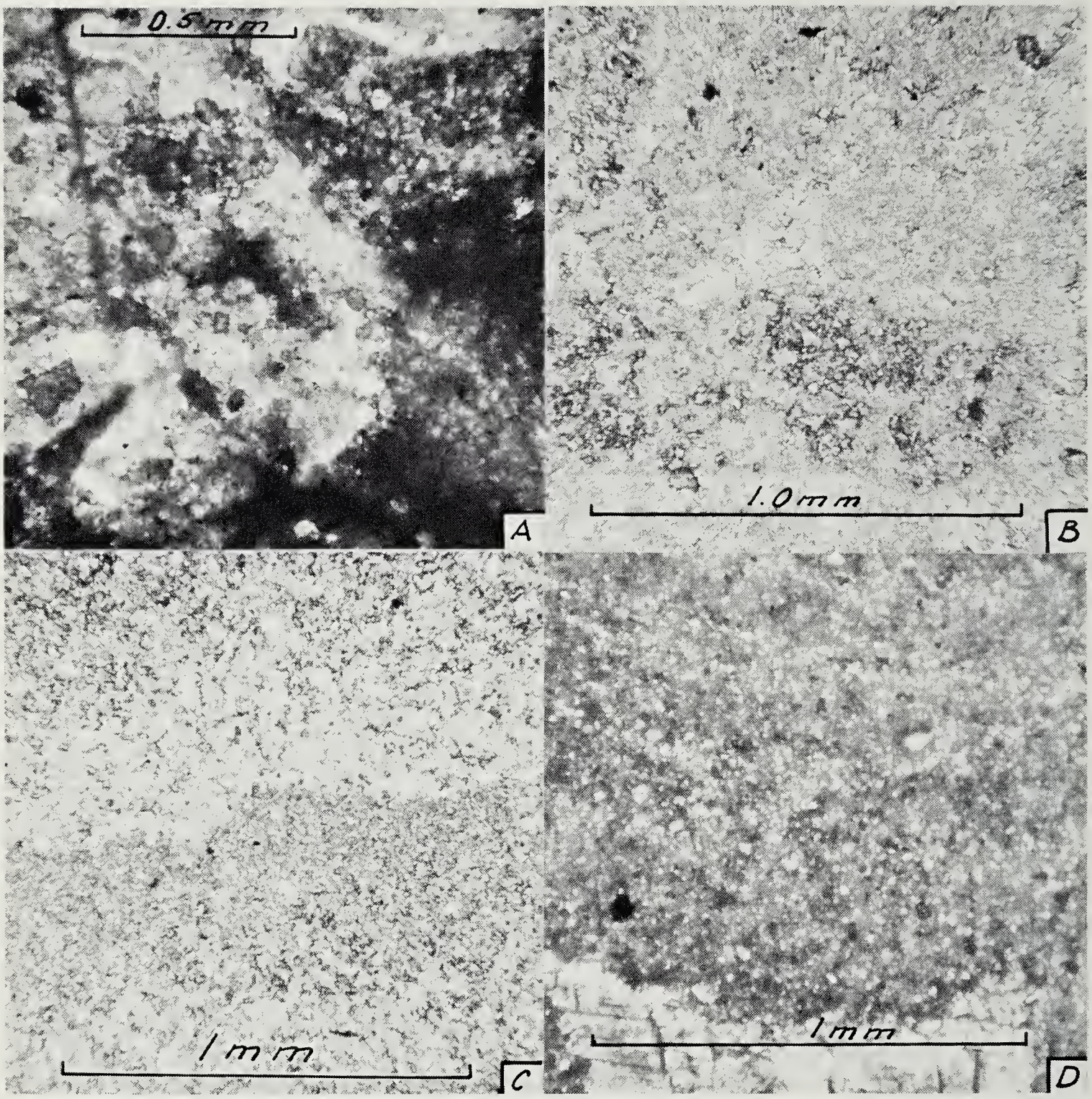
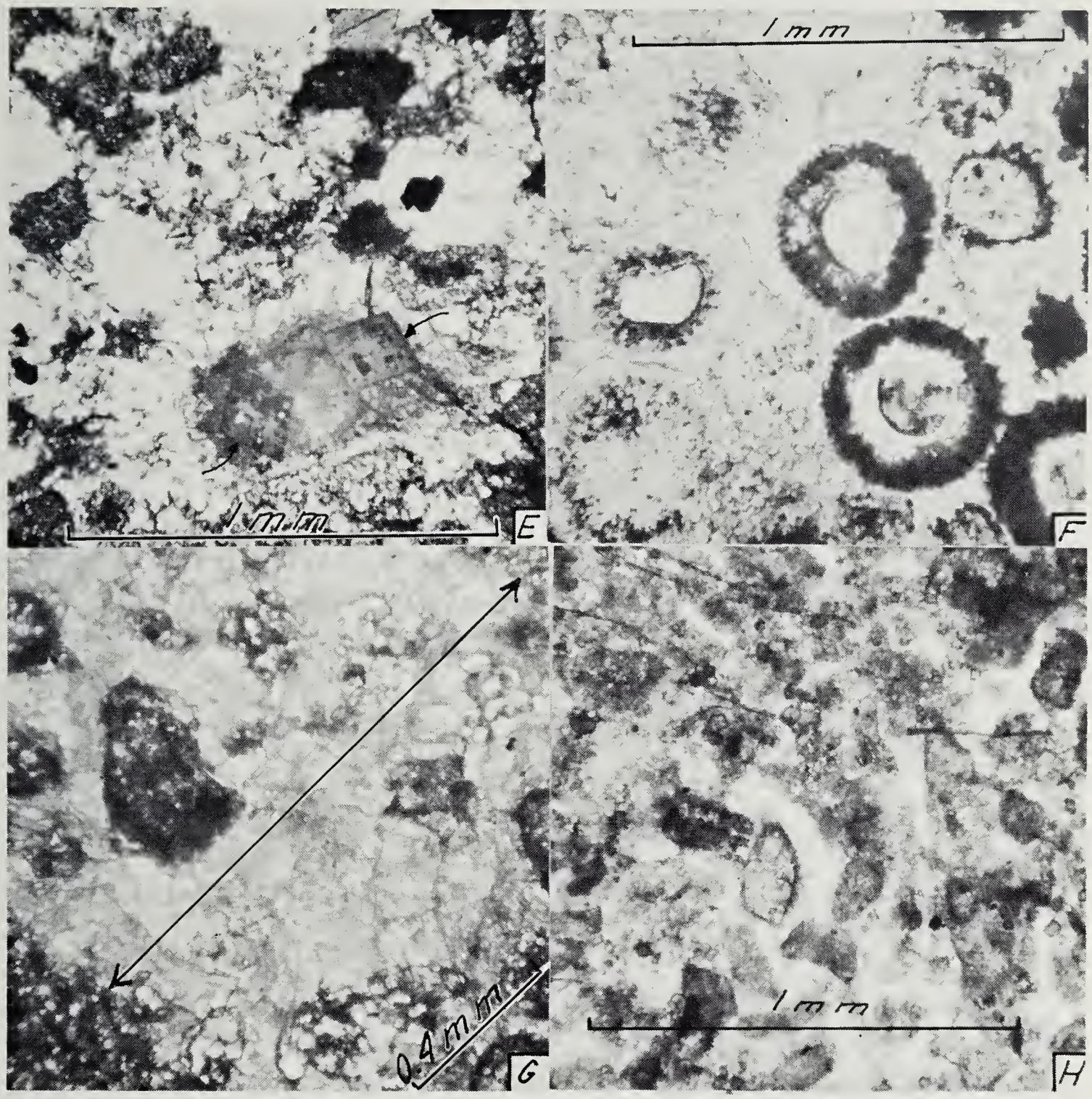


FIGURE 6.—A. Ribbon-mottled unit, microfacies 1 and 2, sample RR-5, section 8. Note microfacies 1 (micrite), the light area in the upper left portion of the photomicrograph, in contact with microfacies 2 (dolomicrite), the dark area in the lower right portion of the photograph. Locally there may be intrasparite, and dolomitization may transect bedding laminations. Nicols not crossed.

B. Intermediate limestone unit, microfacies 3, sample BM-6, section 14. Note the faint outline of intraclasts which are composed of similar material as the matrix. Recrystallization of sparry calcite gives the hand specimen a coarsely crystalline appearance. Nicols not crossed.

C. Laminated unit, microfacies 5, sample FB-2, section 4. This is the transitional (micrite) zone from the ribbon-mottled unit. The darker laminae are dolomitized as in microfacies 2. Nicols not crossed.

D. Laminated unit, microfacies 7, sample FB-4, section 4. Dolomicrite with occasional subhedral to anhedral dolomite. Nicols not crossed.



E. Dolomite unit, microfacies 8, sample FB-6a, section 4. Poorly rounded quartz grains (probably the result of etching by dolomite) are characteristic. May be feldspathic. Note the two dolomite euhedra below the center of the field of view. Nicols crossed.

F. Dolomite unit, microfacies 9, sample RR-24, section 8. The oolites are opaline (silicification). Phantom oolites are seen to the left in the field of view, the result of recrystallization into microcrystalline silica. Nicols crossed.

G. Dolomite unit, microfacies 11, sample RR-13b, section 8. Dolomicrite overlain by dismicrite (not illustrated) which (intradolomicrite) fills a mud crack in the dolomicrite. The arrow indicates the extent of the mud crack. Nicols not crossed.

H. Dolomite unit, microfacies 12, sample RR-12b, section 8. Disrupted and pelletoidal material is illustrated in the photomicrograph; it is found between the stromatolite structures (not illustrated). The recrystallized dolomite is euhedral to anhedral but the sample is predominantly made up of calcite. Nicols not crossed.

units, but they are probably more numerous than recorded. They may not always be apparent in outcrop, but they manifest themselves on polished surfaces or in thin section (Tarkoy, 1967, Fig. 24, p. 63). Therefore the environment was probably shallow enough to allow occasional exposure and desiccation.

The rare occurrence of oscillation ripple marks generated by the to-and-fro motion of the water agitated by waves is indicative of an environment above wave base. .

Intraformational conglomerates particularly common in the intermediate limestone unit and the dolomite unit are formed by

> . . . submarine erosion (such as might be caused by storm waves or underwater slides), by mild tectonic upwarps of the sea floor, or by low tides allowing wave attack on exposed, mud-cracked, carbonate flats. (Folk, 1962, p. 63)

Oolites, almost totally inconspicuous unless silicified, are found in the dolomite unit and they form

> . . . where water saturated with calcium carbonate is drifted backwards and forwards over a shallow sea floor in the track of tidal currents. The depth of water is never very great, usually not more than 20 feet, and the sea floor is so scoured by currents that all traces of micrite are winnowed away. The grains which remain are kept in motion, and acting as nuclei, become encased in concentric layers of carbonate precipitate. (Hatch and Rastall, 1965, p. 201)

The peculiar laminated aspect of the laminated unit may imply algal origin as stated previously. This may indeed be the case but the writer is hesitant to endorse the theory. Nevertheless, the regularity of the unit implies relatively deeper water and conditions of lesser agitation.

In discussing the ecology of faunal assemblages, Lochman and Duncan (1944, p. 31) stated:

> . . . the assemblage of the *Aphclaspis* zone, rigidly restricted to five trilobite genera throughout the entire country, and represented by a large number of individuals, may indicate the introduction of cooler waters.

Not only are the stromatolites a significant feature in the upper portion of the Maynardville Formation, but they are also of definitive environmental significance. These algal structures are

> . . . characteristically developed in continuous mats and algal-bound sediments from the marine, intertidal mud-flat environment, mainly in the protected locations of re-entrant bays and behind barrier islands and ridges where wave action is usually slight. (Ginsburg *et al.*, 1964, p. 77)

Problem of Group Classification.— Mottled limestone has been described from all limestone lithosomes of the Conasauga Group, (the Rutledge, the Craig Limestone Member of the

Rogersville Shale, the Maryville, and the Maynardville), but no mottled limestone has been reported from within the Knox Group. The dolomite lithology, the presence of stromatilites and occasional chert typical of the upper Maynardville is exceptional in the Conasauga Group in in east Tennessee except for the cherty stromatolite reef limestone in the Nolichucky Shale. Chert and oolites are abundant and stromatolitic dolomite comprises up to 60 per cent of the Copper Ridge (Harris, 1966, p. C49), whereas the same lithologies are only quantitatively important within the Maynardville.

The writer believes that the above implied lithologic relations confirm the transitional nature of the Maynardville Formation. The problem is whether it is necessary for such a distinctly transitional unit as the Maynardville Formation to be placed within any particular group, namely, the underlying Conasauga or the overlying Knox. However, since the general consensus of most writers is to place the Maynardville within the Conasauga Group, the writer favors acceptance of this classification.

The lower formational boundary of the Maynardville is considered here as occurring below the first appearance of ribboned or mottled limestone with no more than two continuous feet of olive-gray shale above the contact. The criterion is practicable for mapping traceability because it is relatively continuous and conspicuous.

The relative abundance of typical Copper Ridge and Maynardville lithology is used to place the upper boundary of the Maynardville Formation. The abundance of stromatolites is reliable on outcrop and chert is reliable in covered intervals.

Acknowledgments

The author is grateful to Professor J. M. Dennison of the University of North Carolina at Chapel Hill for his inspiration and guidance and to Professor A. V. Carozzi of the University of Illinois at Urbana for his constructive criticism of the manuscript. I am grateful for material assistance from Jos. S. Ward and Assoc., Caldwell, N.J.

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DIBUNOPHYLLID CORALS FROM THE HOUX LIMESTONE (PENNSYLVANIAN) IN NORTH CENTRAL MISSOURI

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ABSTRACT. — *Dibunophyllum randolphensis,* a new species, is described from the Houx Member, a limestone, of the Little Osage Formation, Desmoinesian, of north central Missouri. The occurrence and distribution of this species in north central Missouri are recorded.

The genus *Dibunophyllum* contains those solitary, rugose corals which are characterized by a narrow, web-like, axial column. Members of this genus, referred to as [the] dibunophyllids, are present, often in large numbers, at or near the base of the Houx Member of the Little Osage Formation (Marmaton) in Boone, Randolph and Howard Counties in north central Missouri (fig. 1). These corals occur in the relatively pure limestones of the Houx, within the basal four to six inches, except where the base of the Houx is argillaceous (fig. 2). Only one dibunophyllid specimen was found in the Houx above its basal part. All of the specimens of *Dibunophyllum* collected belong to a

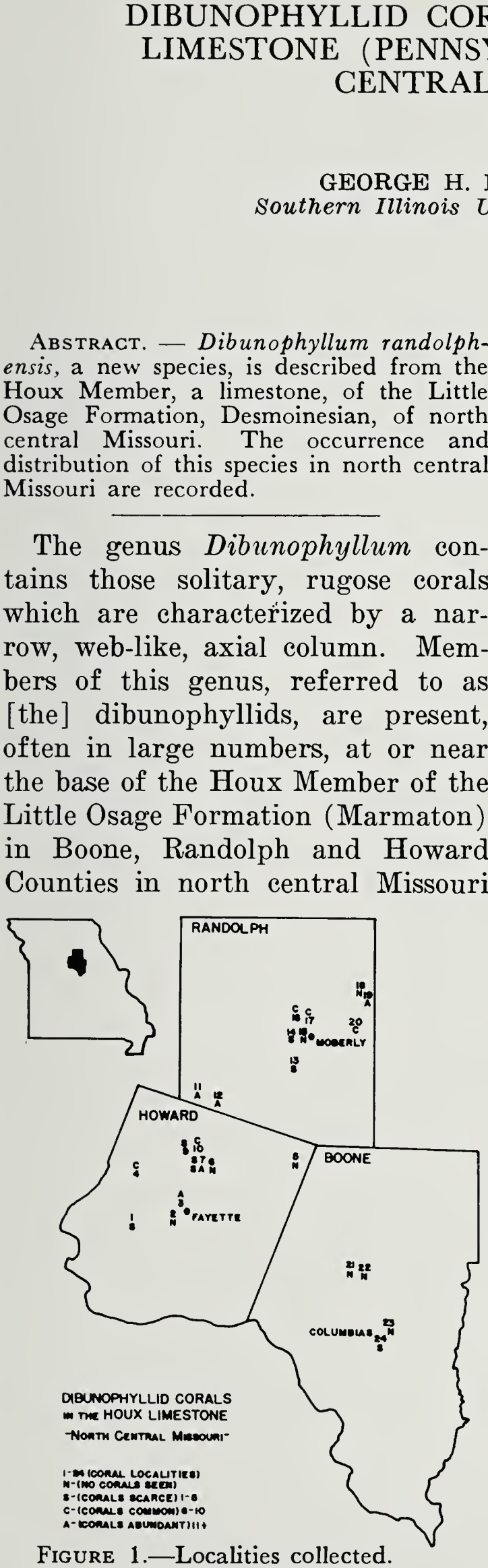


FIGURE 1.—Localities collected.

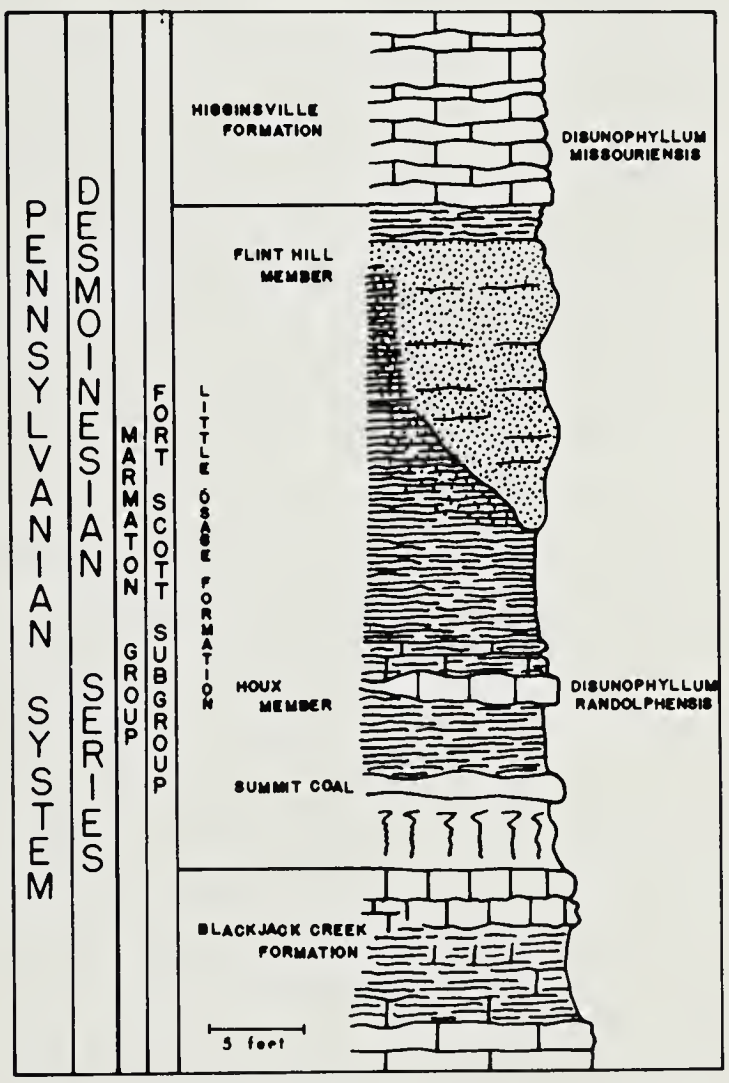


FIGURE 2. — General columnar section of the Fort Scott Subgroup (after Searight and Howe, 1961) showing the stratigraphic occurrence of *Dibunophyllum missouriensis* (Fraunfelter, 1965) and *D. randolphensis.*

single new species described here as *D. randolphensis*. The relative abundance and widespread geographic occurrence of this species make it useful as a stratigraphic marker.

Karl Looff brought these corals to the writer's attention. A paper dealing with the occurrence and distribution of the dibunophyllid corals in the Houx was presented before the annual meeting of the Missouri Academy of Science at Rolla, Missouri, April 29, 1967. The collecting localities are, for the most part, sections measured by Jeffries (1958).

Systematic Paleontology

Family AULOPHYLLIDAE Dybowski, 1873

Genus Dibunophyllum Thomson and Nicholson, 1876

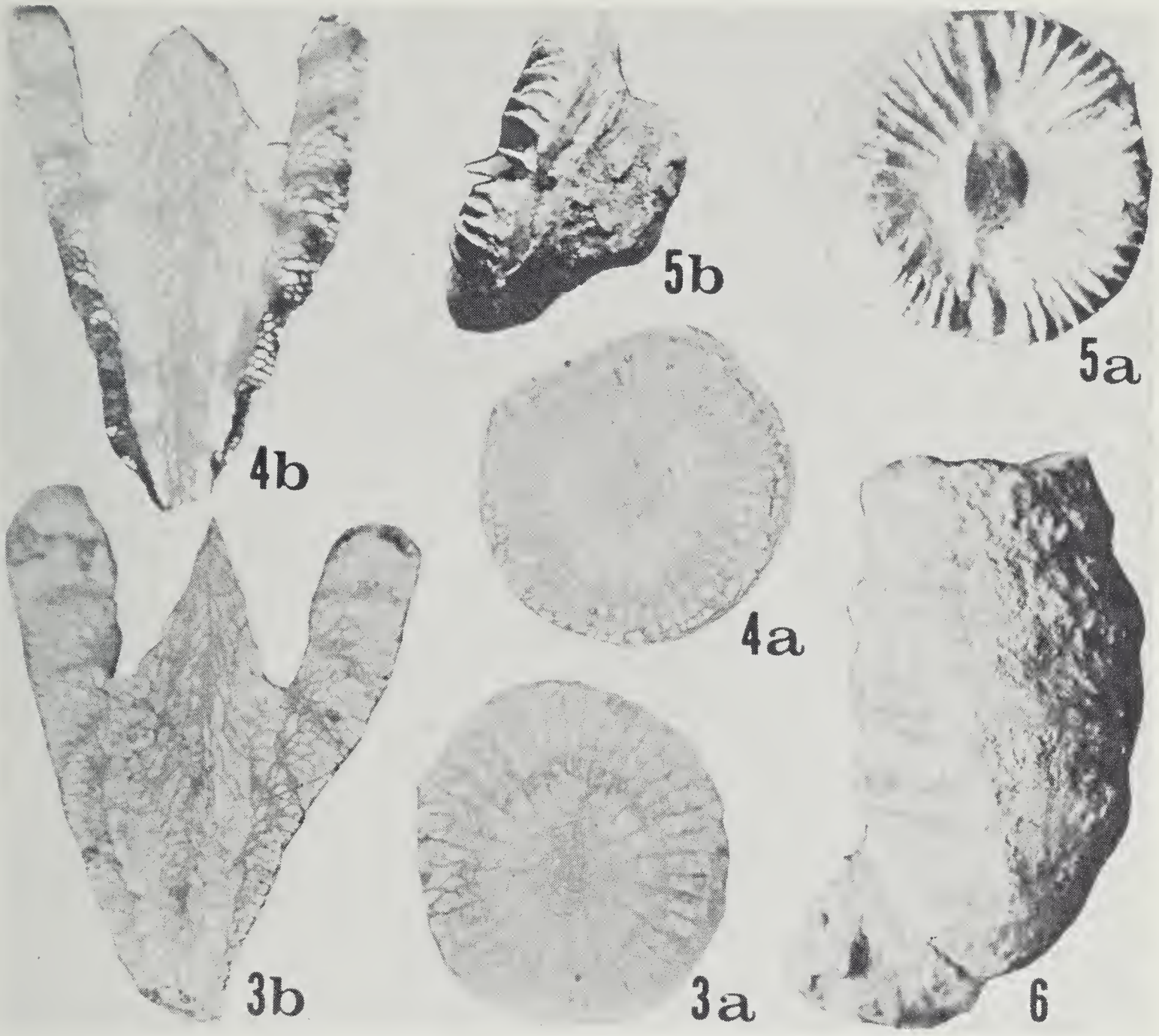
Jeffords, R. M., 1948, Journal of Paleontology, Vol. 22, No. 5, pp. 617-618.

DIBUNOPHYLLUM RANDOLPHENSIS, New Species

Corallites are small (figs. 3-6), ceratoid to turbinate. Calyx deep with prominent axial boss formed by flattened median lamella. Theca thin, annuli of growth prominent externally. Slightly weathered specimens exhibit well-developed septal grooves and interseptal ridges. Length of specimens ranges from 6 to 21 mm. and diameter from 7.5 to 11 mm.

In transverse section, one paratype measures 9 mm. in diameter just below the base of the calyx. There are present 20 major and 20 minor septa, the former extending from half way to nearly all the way to the axis from the periphery. The counter septum is long and attached to the median lamella. The cardinal septum is shortened. Septa are thin and zigzag near the periphery, thicken from middle of dissepimentarium to inner edge of dissepimentarium and gradually thin towards center of tabularium. Septa are thin and zigzag from center of tabularium to axial area. Minor septa are confined to the dissepimentarium. Septa are well-developed and evenly disposed radially. Dissepimentarium extends about half way from periphery to axis. Dissepiments are largely concave peripherally, but may be straight or concave axially; largely complete. Axial structure is strongly dibunophylloid. Median lamella flattened parallel to axis of curvature of corallite.

In longitudinal section, another paratype measures 10 mm. in maximum diameter and 13.5 mm. in length. Outer dissepiments elongate, nearly horizontal; inner dissepiments semi-circular; all convex distally or axially. Rows of dissepiments increase from one in younger growth stages to seven in older stages of growth. In older stages inner rows are steeply inclined to nearly vertically disposed axially. Walls of innermost dissepiments are thickened, forming a distinct boundary between dissepimentarium and tabularium. Tabulae largely incomplete, horizontal or inclined and relatively widely-spaced. Tabulae lean against numerous tabellae, which are less convex peripherally, more numerous and disposed at a higher angle distally. Tabellae are inclined against a thin, sinuous median lamella. Axial column well-developed. Flattened median lamella produces a pointed axial



FIGURES 3-6.—*Dibunophyllum randolphensis,* new species: 3A. Transverse and 3B. longitudinal sections of the Paratypes (SIU Museum No. 2325). 4A. Transverse and 4B. longitudinal sections of paratypes (SIU Museum No. 2326). 5A. Calical and 5B. lateral views of a turbinate corallite. Paratype (SIU Museum No. 2327). 6. Lateral view of a subcylindrical corallite. Holotype (SIU Museum No. 2328). (All X4).

boss in section across axis of curvature of growth of corallite. Calyx 4 mm. deep.

Etymology—From the abundant occurrence of the species in Randolph County, Missouri.

DISCUSSION

D. randolphensis n. sp. differs from all other North American Pennsylvanian species of the genus *Dibunophyllum* with well-developed axial columns in that it possesses only 20 major septa at the base of the calyx. Other species with well-developed axial columns average from 24 to 34 major septa at the base of the calyx (Fraunfelter, 1965 and Cocke, 1966).

D. randolphensis n. sp. possesses 20 major septa on the average, while *D. missouriensis* Fraunfelter averages 30 major septa. The coralla of

D. randolphensis n. sp. average about nine mm. in maximum diameter, while those of *D. missouriensis* Fraunfelter average about 16 mm. The web-like axial column is less tightly developed in *D. randolphensis* n. sp.

Collecting Localities

1. Howard County, about six miles southeast of Glascow in cut north of gravel road, in NE NW NW Sec. 15, T. 50 N., R. 17 W.
2. Howard County, about three miles west of Fayette in north ditch of gravel road in SE SW SW Sec. 8, T. 50 N., R. 16 W.
3. Howard County, about one mile northwest of junction of County Road FF and Missouri Highway 5 in Fayette, along north side of County Road FF in SE SE SE Sec. 33, T. 51 N., R. 16 W.
4. Howard County, about three miles southeast of Glascow in tributary to Hurricane Branch in W 1/2 NW NW Sec. 26, T. 51 N., R. 17 W.
5. Howard County, about 2.5 miles northeast of Bunker Hill in Blue Bluff near center of SE SW Sec. 10, T. 51 N., R. 14 W.
6. Howard County, about seven miles northeast of Fayette in southwest ditch of gravel road north of farm house in NW SE NE NW Sec. 8, T. 51 N., R. 15 W.
7. Howard County, about four miles southeast of Armstrong in road cut along north side of gravel road just west of Mud Creek in SE SE SW Sec. 6, T. 51 N., R. 15 W.
8. Howard County, about 6.5 miles north of Fayette in southwest ditch of gravel road on south bluff of Mud Creek in SE SW SE Sec. 1, T. 51 N., R. 16 W.
9. Howard County, about 1.3 miles west of Armstrong in south road ditch along County road U just west of bridge over Ganaway Creek in NW SE NW Sec. 36, T. 52, N., R. 16 W.
10. Howard County, about two miles east of Armstrong in north ditch gravel road in SW NW NE Sec. 36, T. 52 N., R. 16 W.
11. Randolph County, about three miles northeast of Roanoke along northwest side of gravel road in NE NE NE Sec. 35, T. 53 N., R. 16 W.
12. Randolph County, about two miles northwest of Yates in east bank of tributary to Silver Creek in SW SE NW Sec. 5, T. 52 N., R. 15 W. just north of gravel road.
13. Randolph County, about 3.5 miles north of Higbee in stream bed along gravel road in E 1/2 NE SW Sec. 29, T. 53 N., R. 14 W.
14. Randolph County, about two miles northwest of center of Moberly in stream banks in SE SE SW Sec. 27, T. 54 N., R. 14 W.
15. Randolph County, about 1.6 miles northwest of center of Moberly along north-flowing stream feeding Moberly Lake in center S 1/2 SW SW Sec. 26, T. 54 N., R. 14 W.
16. Randolph County, about six miles northwest of Moberly in north highwall of abandoned strip pit just east of gravel road in SE SW NW Sec. 9, T. 54 N., R. 14 W.
17. Randolph County, about four miles northwest of center of Moberly in outcrops at southeast end of Moberly Lake about 0.1 miles west of gravel road in center W 1/2 SE NW Sec. 14, T. 54 N., R. 14 W.
18. Randolph County, about 2.5 miles northeast of Milton in small drainage north of gravel road and in road ditches in SW SW NE Sec. 1, T. 54 N, R. 13 W.
19. Randolph County, about 2.5 miles northeast of Milton and just east of farm house between gravel road and Flat Creek in NE NE SE Sec. 1, T. 54 N., R. 13 W.
20. Randolph County, about one mile southwest of Milton in west bank of tributary to Salt River in SW SW NW Sec. 23, T. 54 N., R. 13 W.
21. Boone County, about 5.5 miles east of Harrisburg in stream bed of tributary to Silver Fork about 0.1 mile south of Missouri Highway 124 in SE SW SW Sec. 11, T. 50 N., R. 13 W.
22. Boone County, about 4.5 miles north of Hinton in road along east side U.S. Highway 63 just north of junction with Missouri Highway 124 in SE SE NW Sec. 13, T. 50 N, R. 13 W.
23. Boone County about five miles northeast of Columbia in southeast ditch of gravel road in NW NW SE Sec. 27, T. 49 N., R. 12 W.
24. Boone County, just east of Columbia in north highwall of upper pit of brick plant in NE SW Sec. 8, T. 48 N., R. 12 W.

Types

Southern Illinois University Museum No. 2325—Paratypes (loc. 11), No. 2326—Paratypes (loc. 11), No. 2327—Paratypes (loc. 18), and No. 2328—Holotype (loc. 18).

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ISOLATION AND FRACTIONATION OF LIPOPOLYSACCHARIDES FROM SERRATIA MARCESCENS BIZIO

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Abstract. — Endotoxin from *Serratia marcescens* Bizio and its hot phenol treated product were shown to be heterogeneous by Sepharose 4B gel permeation chromatography. The chemical composition of various fractions and the effect of hot phenol on endotoxin are described.

Lipopolysaccharides (LPS) are characteristic components of the cell envelopes of Gram-negative bacteria. LPS are present in the outer membrane of the cell envelope as a protein complex, commonly called endotoxins. The lipopolysaccharide portion of the endotoxin complex is a phosphorus containing heteropolymer consisting of a lipid moiety covalently bound to a core polysaccharide.

Lipopolysaccharide preparations isolated from any of the Gram-negative bacteria elicit similar biological effects. They are antigenic, highly toxic, and pyrogenic. A single dose of endotoxin will cause hemorrhage and regression of tumor tissues. In lethal doses they induce characteristic hemodynamic effects resulting in irreversible shock. On the other hand, the chronic administration of small amounts of the endotoxin to animals induces resistance to various infection, lethal doses of x-ray, and traumatic and hemorrhagic shock.

In order to study the endotoxin complex or the LPS moiety, homogenenity is essential, as it is for studies of biosynthesis, chemical structure, and the investigation of biological function. Pure and homogeneous compounds are needed for the study of the mechanisms in which endotoxin or LPS elicits various biological reactions. Contamination of an incompletely purified sample would obviously influence biological effects. To obtain the endotoxin, the cells have to be extracted with different types of reagents. So far, all available methods reported yielded products contaminated with various substances such as nucleic acids, loosely bound proteins, and free lipids. The extent and kind of contamination depend upon the extraction techniques employed.

In this paper we report the isolation, purification, and fractionation of an endotoxin from *Serratia marcescens* Bizio.

Materials and Methods

Serratia marcescens, Bizio strain grown on an inorganic medium, was supplied by General Biochemicals, Chagrin Falls, Ohio. The cells were harvested at the late log phase. Semi-wet cells were extracted with 5% trichloroacetic acid (TCA) (Boivin, *et al.,* 1933). After removal of TCA by dialysis, the extract was submitted to repeated ultracentrifugation at 105,000 x g until freed of nucleic acids. The bottom gel layer was

lyophilized to give fraction LPS-U. Chloroform-methanol extraction (2:1 v/v) of fraction LPS-U removed the contaminating free lipids and gave fraction LPS-UE (Figure 1). In a

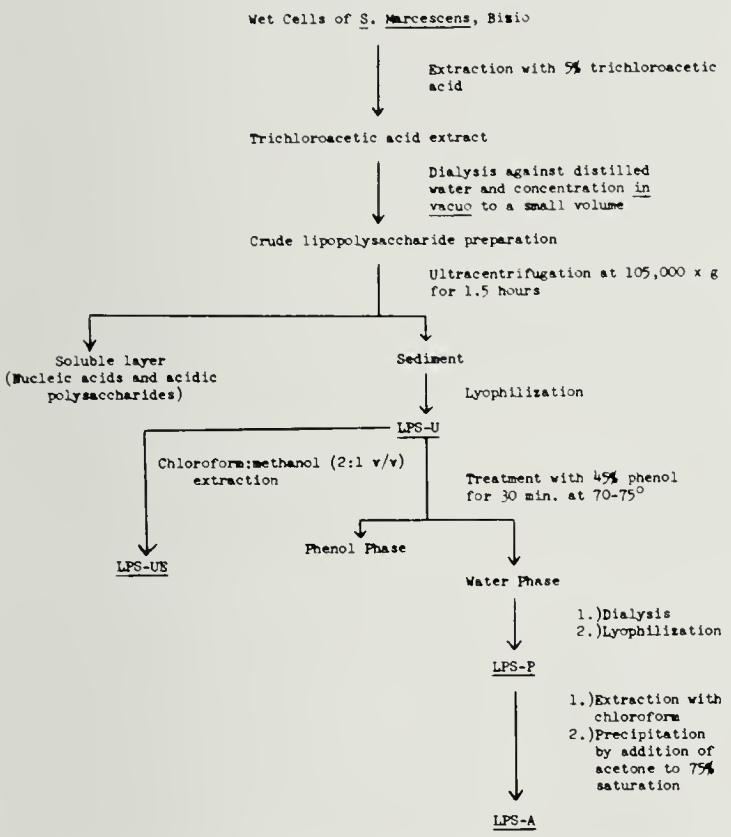

FIGURE 1.—Procedure for the Isolation of Lipopolysaccharide Fractions.

separate experiment, fraction LPS-U was submitted to hot aqueous phenol treatment according to the method of Westphal (Westphal, *et al.*, 1952). The LPS preparation obtained from the aqueous phase was submitted to chloroform-methanol (2:1 v/v) extraction and acetone precipitation (75% acetone in water); then recovered as fraction LPS-A. Both fractions LPS-UE and LPS-A were analyzed for their carbohydrate, protein, and lipid contents. Carbohydrate analyses included the determination of anthrone-positive carbohydrates (hexoses) and uronic acids. Paper chromatographic analyses of the hydrolyzed samples for monosaccharides were performed by the descending method on Whatman No. 1 paper with the following solvent systems:

A. Ethyl acetate: pyridine: water (3.6:1:1.5)

B. Butanol: pyridine: water (11:3.6:5.5)

Protein was determined according to the amount of amino-nitrogen; lipid analysis included fatty acid determination. The analytical methods were the same as those previously applied (Alaupovic, *et al.*, 1966).

Column chromatography of fractions LPS-UE and LPS-A was performed in Sepharose 4B gel. Fifty milligrams of the samples were dissolved in 5 ml of 0.15 M NaCl in 0.05 M phosphate buffer, pH 7.5 and carefully layered on the top of the column (1.5 x 100 cm). Fractions were eluted by the same buffer (1 ml per fraction). Aliquots of 0.1 ml were taken for anthrone-positive carbohydrate analysis. Fractions under the same peak were pooled and submitted to dialysis and later lyophilization.

The major peaks from fraction LPS-UE collected by the method described were dissolved in 0.5% sodium dodecyl sulfate (SDS) in the same buffer and rechromatographed in a column equilibrated with 0.2% SDS in distilled water.

Results and Discussion

The yield of extracted endotoxin (fraction LPS-U) was 1.2% based on the dry weight of the cells. Fraction LPS-UE obtained by chloroform-methanol extraction of fraction LPS-U was about 50% of the original sample. LPS-A differed from fraction LPS-UE in that it was obtained after phenol extraction (Fig-

ure 1) and was supposedly devoid of the protein moiety. Paper chromatographic analysis indicated that both fractions (LPS-UE and LPS-A) contained glucose, mannose, galactose, rhamnose, glucosamine, uronic acids, and heptose. With the exception of uronic acid, the other sugars represented the sugars of the basal core of the bacterial lipopolysaccharide. The presence of uronic acid has not been reported in other species of Gram-negative bacteria. Table 1 shows the chemical composition of fractions LPS-UE and LPS-A. Fraction LPS-A differed, as expected, from fraction LPS-UE by its content of protein (the amino-nitrogen value was 0.16%, compared to 0.5% for fraction LPS-UE) and fatty acids (4.1% compared with 20.0% for fraction LPS-UE). The analytical results clearly indicated that phenol treatment removed most of the protein moiety and some fatty acids from fraction LPS-UE. As would be expected, the carbohydrate content of fraction LPS-A was

TABLE 1. Chemical composition of isolated lipoplysaccharide fractions.

Fractions	Anthrone Positive Material %	Uronic Acid %	Fatty Acids %	Amino-Nitrogen %
LPS-UE.....	27.0	9.2	20	0.5
LPS-A.....	30.9	12.7	4.1	0.16

slightly higher. The isolation and characterization of the protein moiety in the phenol phase is in progress.

Two distinct peaks were obtained when fraction LPS-UE was submitted to column fractionation on Sepharose 4B (Figure 2). The per cent yield and chemical composition are presented in Table 2. Because of the low recovery of peak two (fraction LPS-UE-2), fatty acid analysis was not performed. The composition of peak one (LPS-UE-1) was similar to the starting material (LPS-UE) with a slight decrease in carbohydrates as well as fatty acids. Fraction LPS-UE-2 was higher in both hexose and uronic acids. It is possible that some lipid was present.

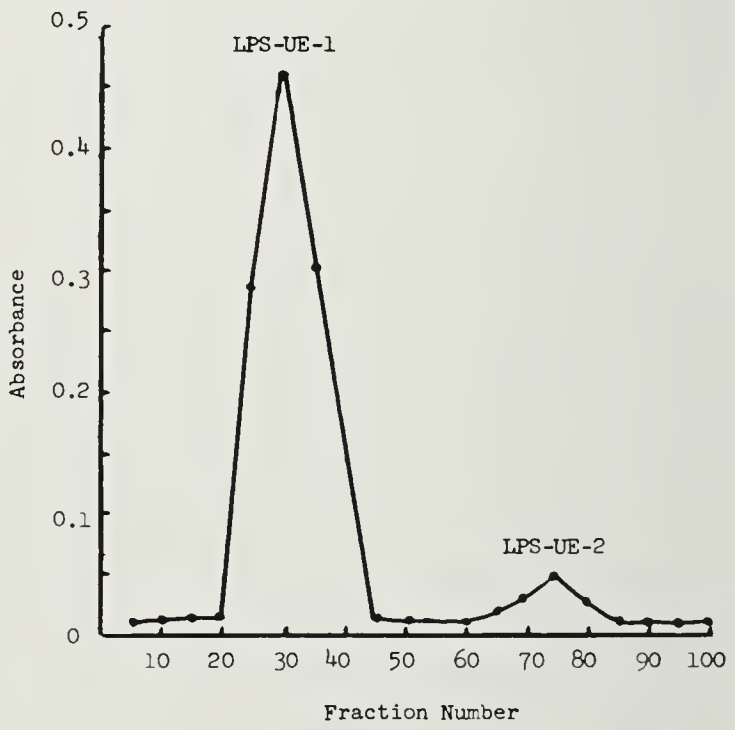

FIGURE 2. — Column Fractionation of Fraction LPS-UE on Sepharose 4B. Volume collected 1 ml per tube. Flow rate 16 ml per hour. Column was monitored by anthrone reaction on 0.1 ml aliquots of every five tubes.

TABLE 2. Chemical composition of LPS fractions from Sepharose 4 BColumn.

Fractions	Yield %	Anthrone Positive Material %	Uronic Acid %	Fatty Acid %
LPS-UE-1.....	90	25.5	7.5	18.4
LPS-UE-2.....	10	67.2	10.5	N.D.

When fraction LPS-A was fractionated under the same conditions, two distinct peaks were again obtained, although neither peak yielded enough material for analysis. It is likely that when the protein moiety was removed by phenol extraction, the size of the majority of the lipopolysaccharide was decreased to such an extent that retention of the smaller molecules in the column occurred. Column chromatography of fraction LPS-A on Sephadex G-200 or Sephadex G-100 may clarify this point.

Our results show that the previously mentioned "purified" endotoxins were heterogeneous. Heterogeneity of fraction LPS-U has been shown by ion exchange chromatography (Nowotny, 1966). Fractionation of bacterial lipopolysaccharide on agarose had been attempted, but no separation was obtained (Cameron, 1968).

It has been reported that sodium dodecyl sulfate and sodium deoxycholate caused reversible dissociation of LPS preparations (Oroslan and Mora, 1963; Rudbach, *et al.*, 1966). In order to demonstrate any possible subunit aggregation of peak one (fraction LPS-UE-1), it was dissolved in 0.2% SDS and chromatographed in a column of Sepharose 4B equilibrated with 0.2% SDS. Only one peak was eluted in the void volume. It is not known if dissociation occurred, but recombination may take place during the recovery procedure. Our results, however, are in agreement with those reported in the case of fractionation of LPS from *E. coli* in SDS (McIntire, *et al.*, 1967). Recently, LPS from *E. coli* was fractionated into three distinct peaks on Sephadex G-100 with 1% sodium deoxycholate after the LPS was submitted to dinitrophenylation (McIntire, *et al.*, 1969). Further dissociation and fractionation studies in sodium deoxycholate and quanidine hydrochloride solution may show if fraction LPS-UE-1 was a monomer or an aggregate of subunits.

LPS fractions separated and recovered by the procedures described will serve as starting material for subsequent immunochemical studies. Previous work on fraction LPS-U (Alaupovic, *et al.*, 1966) showed that there were two immunoprecipitin lines when fraction LPS-U was allowed to react with anti-whole cell serum. It is hoped that fractions LPS-UE-1 and LPS-UE-2 will give immunoprecipitin lines which correspond to the two lines observed in LPS-U. Our long-term objective is to prepare an immunologically pure

LPS with minimum toxic properties. Once such a compound is obtained, not only can the chemical composition and biological properties of LPS be determined, but also the development of vaccines against pathogenic Gram-negative bacteria should be possible.

Acknowledgment

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THE GENUS SPHAGNUM IN ILLINOIS

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Abstract. — Fourteen species and two varieties of the peat moss, *Sphagnum*, occur in Illinois. Keys, descriptions, distribution and habitat data are given for each taxon.

Various species of the genus *Sphagnum* (peat or bog moss) have been reported from Illinois in a number of bryological and ecological papers (Calkins 1910; Taylor, 1920; Waterman, 1921, 1923, 1926; Kurz, 1928; Hague, 1934; Richards, 1940; Vaughan, 1941; Arzeni, 1941; Hatcher, 1952; Reichle and Doyle, 1965; Skorepa and Snider, 1967); however, no systematic account of the genus in the state has ever been published. This paper will summarize the species of *Sphagnum* known from Illinois, present keys and descriptions, and provide distributional and habitat data.

Andrews has done much to alleviate the problem posed by intraspecific variation by making a thorough study of both North American and European specimens and reducing a large number of species and varieties to synonomy. In presenting his concepts and theories, Andrews (1911-61) discussed a natural classification of the peat mosses in a series of "Notes on North American *Sphagnum*".

Most of the characters used to separate the species need not be a great problem if care is used in preparing the specimens for examination. For a discussion of methods helpful in the study of *Sphagnum*, reference should be made to Blomquist (1938).

The key and descriptions are based on Illinois material and cover the important features of the species discussed. The taxonomic arrangement and species concepts are based on Andrews (1913). For illustrations to a number of the species, reference can be made to Blomquist (1938) and Welch (1957). Collections used in this study were obtained from the herbaria of the Illinois Natural History Survey (ILLS), University of Illinois (ILL), Field Museum of Natural History (F), Southern Illinois University (SIU), and Duke University (DUKE).

Morphology

The genus is composed of plants ranging in size and habit from short mats or tufts of just a few centimeters in height, to large, erect specimens many centimeters in height. Gametophyte development is apical, and rhizoids are absent in the mature plant. The stem is comprised of three regions. The central, or innermost, region consists of thin-walled, hyaline, parenchymatous cells. Surrounding the central region is usually a region of colored, thick-walled, prosenchymatous cells, and the outermost region, the cortex, consists of hyaline cells which vary from one to five cells in thickness, are often porose, and may or may not

contain spiral thickenings. Branches are of two forms, spreading and drooping, each containing a single, cortical layer of cells. The branches are normally intermixed in fascicles arranged spirally around the stem. Near the apex of the stem the branches are crowded, forming a tuft or capitulum. Branch and stem leaves are spirally arranged and are composed of a single layer of two types of cells; narrow chlorophyll-bearing cells surrounding larger, hyaline cells which are porose and usually contain spiral fibril-bands. Larger, irregular openings, or resorbed areas, in the hyaline cell walls of the leaves may or may not be present. In some cases leaf margins may be composed of few to numerous rows of narrow, elongated cells. In others the margin may be composed of a row of chlorophyllose cells bearing a resorption furrow composed of a strip of incompletely developed hyaline cells along the outer edge. Plants may be monoicous or dioicous with archegonial and antheridial branches distinct. Perichaetial leaves are larger and much differentiated from branch leaves and enclose the capsule until it reaches maturity. The capsule is globose, ranging from brown to black at maturity. An annulus and peristome are lacking. After dehiscence the capsule is urn-shaped to cylindrical. Spores are tetrahedral and yellowish to brown.

Key and Descriptions to the Illinois Taxa of Sphagnum

1. Cortical cells of stem and branches reinforced with fibril-bands .....2.
   2. Chlorophyllose cells of branch leaves elliptical in cross-section, appearing centrally positioned, entirely included between both surfaces of adjacent hyaline cells .....*S. magellanicum* (1)
   2. Chlorophyllose cells of branch leaves triangular in cross-section, base of triangle exposed on inner surface of leaf .....3.
      3. Chlorophyllose cells of branch leaves isosceles-triangular in cross-section, walls of hyaline cells adjacent to chlorophyllose cells smooth ....*s. palustre* (2)
      3. Chlorophyllose cells of branch leaves equilateral-triangular in cross-section, walls of hyaline cells adjacent to chlorophyllose cells with fringe-like fibrils .....*S. imbricatum* (3)
1. Cortical cells of stem and branches lacking fibril-bands .....4.
   4. Cortical cells of branches uniform, each with a pore at the upper end; chlorophyllose cells of branch leaves elliptical in cross-section, closer to the outer surface, entirely included between surfaces of adjacent hyaline cells .....*S. compactum* (4)
   4. Cortical cells of branches of two kinds, the large retort-cells with pores and smaller cells lacking pores, or, if uniform, cortical cells without pores; chlorophyllose cells of branch leaves other than elliptical in cross-sections exposed on one or both surfaces of adjacent hyaline cells ..5.
      5. Chlorophyllose cells of branch leaves triangular to trapezoidal or rounded-rectanguar in cross-section, more broadly exposed on the outer surface to equally exposed on both surfaces .....6.
         6. Apex of stem leaves broad, fimbriate-lacerate; branch leaves squarrose when dry..7.
            7. Plants robust, branch leaves squarrose wet or dry, ovate-hastate ....*S. squarrosum* (5)
            7. Plants slender, branch leaves imbricate when moist, ovate-lanceolate.. .....*S. teres* (6)
         6. Apex of stem leaves rounded to acuminate, not fimbriate-lacerate; branch leaves imbricate to spreading when dry .....8.
            8. Cortical cells of stem small, scarcely differentiated from inner cells; branch leaves, when dry, usually twisted at tips .....9.

9. Branch leaves undulate when dry, with spreading, twisted, recurved tips.. .....*S. recurvum* (7)

9. Branch leaves not undulate when dry due to the smaller size of the leaf.. ..S. *recurvum* var. *tenue* (7a)

8. Cortical cells of stem large, thin-walled, in 1-3 layers; branch leaves, when dry, not twisted at tips .....10.

10. Outer surface of branch leaves with few, small, ringed pores in ends and corners of hyaline cells, 2-5 per cell ....*S. cuspidatum* (8)

10. Outer surface of branch leaves with numerous, small, ringed pores in a row along sides of hyaline cells, 10-20 per cell ....*S. subsecundum* (9)

5. Chlorophyllose cells of branch leaves triangular to trapezoidal in cross-section, more broadly exposed on the inner surface ..11.

11. Stem leaves lacerate across the broad, truncate apex ....*S. girgensohnii* (10)

11. Stem leaves not lacerate across apex .....12.

12. Pigment brown, branch leaves spreading .....*S. fuscum* (11)

12. Pigment red, branch leaves imbricate .....13.

13. Outer surface of branch leaves with very small, round, strongly ringed pores (easily observed when stained) in apical portion; branch leaves arranged in five rows ..*S. warnstorfii* (12)

13. Outer surface of branch leaves with large, unringed pores; branch leaves not arranged in five rows .....14.

14. Stem leaves with fibrils faint to lacking, pores few; free convexity of hyaline cells of branch leaves in cross-section less than half their diameter .....15.

15. Stem leaves narrowly lingulate to triangular-ovate, fibrils faint, hyaline cells of stem leaves mostly not divided .*S. capillaceum* (13)

15. Stem leaves broadly lingulate, fibrils lacking, hyaline cells of stem leaves above basal region all divided ..... *S. capillaceum* var. *tenellum* (13a)

14. Stem leaves strongly fibrillose and porose, free convexity of hyaline cells of branch leaves in cross-section more than half their diameter ....*S. tenerum* (14)

1. *Sphagnum magellanicum* Brid.

Plants compact to robust, green to brown, usually tinged pink to red; cortical cells of stem and branches with fibril-bands; outer cells of stem containing 1-2 large, round to elongate pores; cortical cells of branches porose; stem leaves long-lingulate to lingulate-spatulate, hyaline cells non-fibrillose to fibrillose in apex, porose on outer surface, apex broad, rounded; branch leaves imbricate to spreading, ovate, border denticulate near the cucullate apex, hyaline cells fibrillose, porose; chlorophyllose cells elliptic in cross-section, central, entirely enclosed by hyaline cells, walls of hyaline cells adjacent to chlorophyllose cells smooth.

S. magellanicum is one of four species with a reddish color occurring in Illinois. In the field it may be separated from the other three species by its larger, hood-shaped, cucullate branch leaves. Microscopically, it differs in having fibril-bands present in the cortical cells of stem and branches.

Habitat—Thus far found only in boggy situations, commonly forming

hummocks around the bases of higher plants.

Distribution—Lake Co.: Tamarack Swamp, *Hill 255* (F). McHenry Co.: Ringwood, *Vasey s. n.* (F).

2. *Sphagnum palustre* L. *(S. cymbifolium* Ehrh.)

Plants compact to robust, green to tinged with brown; cortical cells of stem and branches with fibril-bands; outer cells of stem cortex containing 1-4 irregularly rounded pores; cortical cells of branches with a single pore; stem leaves spatulate to elongate-lingulate, hyaline cells porose and fibrillose in apical region, apex rounded; branch leaves imbricate to squarrose, ovate, margins involute to the cucullate apex, hyaline cells fibrillose and porose; chlorophyllose cells narrowly isoceles-triangular in cross-section, exposed on the inner leaf surface; walls of adjacent hyaline cells smooth.

S. palustre is one of three species in the state which has cortical cells containing fibril-bands and with large, cucullate branch leaves. It can be separated from *S. magellanicum* by the latter's reddish color, and from *S. imbricatum,* microscopically, by its fringe-like fibrils along the walls of the hyaline cells of the branch leaves.

Habitat—Found in bogs and swampy areas, wet woodlands, and along moist sandstone stream banks.

Distribution—Kendall Co.: Millington Fen, *Mohlenbrock s. n.* (SIU). Lake Co.: Starved Rock State Park, *Umbach s. n.* (F). Clark Co.: Rocky Branch, *Arzeni s.n.* (Duke)

3. *Sphagnum imbricatum* Hornsch. *ex* Russ.

Plants usually robust, green to tinged with brown; cortical cells of stem and branches with fibril-bands, containing on their inner surface a corrugation consisting of ridges and grooves lying in the same direction as the fibril-bands, but more numerous than the bands; cortical cells of stem with 4-10 irregularly rounded pores; cortical cells of branches with 1-2 pores; stem leaves lingulate to slightly spatulate, hyaline cells without pores and fibrils; branch leaves imbricate to squarrose-spreading, ovate, margins denticulate, apex cucullate, hyaline cells fibrillose, porose; chlorophyllose cells equilateral-triangular in cross-section, exposed on inner surface; inner walls of hyaline cells adjacent to chlorophyllose cells with fringe-like fibrils on the wall opposite the chlorophyllose cells.

This species is characterized by the fringe-like fibrils on the walls opposite the chlorophyllose cells.

Habitat—Moist wooded areas and swamps.

Distribution — Fulton Co.: Canton, *Wolf s. n.* (F). Massac Co.: Long Springs, *Schwegman s. n.* (SIU). Pope Co.: Sphagnum Springs, *Schwegman 7* (SIU)

4. *Sphagnum compactum* Lam. & DC.

Plants short, compact, dirty white to green, sometimes with a brownish tinge; cortical cells of stem and branches lacking fibril-bands; outer cells of stem lacking pores; cortical cells of branches with a pore at the upper end; stem leaves concave, short-lingulate to triangular-lingulate, apex slightly lacerate, hyaline cells lacking pores and fibrils; branch leaves usually large, squarrose, ovate-hastate, leaf margin denticulate, involute, toothed at apex, hyaline cells

fibrillose, porose; chlorophyllose cells elliptic in cross-section, not exposed on either surface, but usually nearer the outer surface.

S. compactum is our most common species. In aspect it resembles the above three species, but the leaves are channeled and truncate (but not cucullate) at the apex. The cortical cells of the stem and branches also are not fibrillose. The compact manner of growth, with branches erect and leaves relatively large and fleshy in appearance, as well as a washed-out dirty green color, distinguish this species.

Habitat — Wet meadows, moist woodlands, wet sandstone bluffs and roadside ditches.

Distribution—Cook Co.: *Thieret 975* (F). Jackson Co.: Little Grand Canyon, *Hatcher 947* (SIU). Pope Co.: Lusk Creek Canyon, *Bailey & Swayne 2353* (SIU). Randolph Co.: Rock Castle Creek, *Snider 185* (SIU). Will Co.: Custer Park, *Franzen s.n.* (F). Grundy Co.: Goose Lake Prairie, *Zales 964* (SIU).

5. *Sphagnum squarrosum* Sw. *ex* Crome

Plants normally tall and robust, bright green to yellowish; cortical cells of stem and branches lacking fibril-bands; cortical cells of stem in 2-3 layers, thin-walled, lacking pores; cortical cells of branches composed of smaller, non-porose cells and larger, porose, retort cells with inconspicuous necks; stem leaves long, ovate-lingulate, concave, border of narrower cells extending to base, apex broad, fimbriate-lacerate, hyaline cells lacking fibrils and pores; branch leaves strongly squarrose, spreading or imbricate, ovate-hastate, contracting to an acute, involute, toothed apex, hyaline cells fibrillose, porose; chlorophyllose cells triangular to trapezoidal in cross-section, base exposed on the outer surface, narrow to no exposure on inner surface.

This woodland species is easily recognized by its large size and widely spreading branch leaf tips. It also has a prominent terminal bud similar to *S. teres,* to which it is closely related.

Habitat—Bogs, moist woods, and along sandstone creek banks.

Distribution—Clark Co.: Rocky Branch, *Arzeni s.n.* (Duke). Lake Co.: reported by Reichle & Doyle (1965) in Volo Bog, specimen not examined. Kankakee Co.: Farris Wood, *De Selm 630* (F).

6. *Sphagnum teres* (Schimp.) Angstr. *ex* C. Hartm.

Plants usually slender, green to tinged with brown; cortical cells of stem in 3-4 layers, thin-walled, fibril-bands and pores lacking; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with inconspicuous necks; stem leaves long-lingulate, concave, hyaline cells lacking fibrils and pores, broadly fimbriate-lacerate at apex; branch leaves imbricate to slightly squarrose, ovate-lanceolate, apex involute, toothed, hyaline cells fibrillose and porose; chlorophyllose cells triangular to trapezoidal in cross-section, exposed more on outer leaf surface.

S. teres is a species of wet habitats. It is characterized by its weak habit and large terminal bud. The branches are relatively stiff and slender with leaves appressed when moist but spreading to squarrose when dry.

Occasional robust forms may be separated from *S. squarrosum* which it resembles most by the latter's ovate-hastate rather than ovate-lanceolate branch leaves.

Habitat—Has been found only in Volo Bog adjacent to the floating mat stage.

Distribution — Lake Co.: Volo Bog, *Richards & Fuller 986* (F).

7. *Sphagnum recurvum* P. Beauv.

Plants normally robust, green to yellowish to brownish; cortical cells of the stem scarcely differentiated, lacking fibril-bands and pores; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with inconspicuous necks; stem leaves loosely triangular, hyaline cells normally lacking fibrils and pores, apex mucronate, rounded or truncate and slightly eroded; branch leaves narrowly lanceolate, when dry undulate with spreading, recurved tips, apex involute, slightly toothed, hyaline cells fibrillose, porose; chlorophyllose cells triangular in cross-section, base exposed on outer surface, reaching inner leaf surface.

S. recurvum can be recognized in the field, in dry condition, by the usually undulate, twisted, recurved tips of the branch leaves. When moist, the young pendent branches are in pairs between the rays of the capitulum. Aquatic forms may be confused with *S. cuspidatum,* but the key characters pertaining to the cortical cells will separate the two species.

Habitat — This species may be found as floating mats in bogs, in seepage areas, on moist sandstone bluffs and along creek banks.

Distribution—Cook Co.: Argonne Forest Preserve, *Steyermark 65856* (F). Johnson Co.: Cedar Falls, *Mohlenbrock & Hopkins s.n.* (SIU). Lake Co.: Tamarack Swamp, *Hill 218* (F). McHenry Co.: Ringwood, *Vasey s.n.* (F).

7a. var. *tenue* Klinggr. — Plant smaller, shorter than the species, dry branch leaves scarcely undulate due to its smaller size.

Habitat—Same as for the species.

Distribution—Lake Co.: Wauconda Bog, *Hill 261* (F).

8. *Sphagnum cuspidatum* Ehrh. *ex* Hoffm.

Plants delicate to somewhat robust, green to yellowish; cortical cells of stem thin-walled, in 1-3 layers, fibril-bands and pores lacking; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with inconspicuous necks; stem leaves triangular-ovate, deeply concave, hyaline cells with or without fibrils in apical portion, apex toothed; branch leaves long-lanceolate, involute, apex toothed, hyaline cells fibrillose, porose; chlorophyllose cells trapezoidal in cross-section with broader exposure on the outer leaf surface.

A plant of very wet habitats, *S. cuspidatum* is often submerged and appears weak and limp. The branch leaves are relatively long and narrow and stick together like the point of an artist's brush when drawn from the water.

Habitat—-wet woods and marshes.

Distribution—Cook Co.; Argonne Forest Preserve, *Steyermark 65856* (F). Lake Co.: Cranberry Marsh, *Hill 243* (F). Williamson Co.: Carterville, *Snider 461* (SIU).

9. *Sphagnum subsecundum* Nees *ex* Sturm

Plants small and delicate to robust, highly variable, green to brown to purplish-brown; cortical cells of stem thin-walled, in 1-3 layers, lacking fibril-bands, rarely with pores; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with inconspicuous necks; stem leaves triangular-lingulate to ovate, slightly auriculate, concave, hyaline cells rarely containing fibrils and pores, apex broad, rounded; branch leaves subsecund to imbricate, concave, ovate, acuminate, involute, toothed at apex, hyaline cells fibrillose, on the inner surface of the leaf with a few small, round pores in cell angles, the outer surface with numerous small, ringed, round to elliptic bead-like pores along the sides of the cells; chlorophyllose cells in cross-section truncately elliptic, barrel-shaped, large, exposed on both the inner and outer leaf surface.

S. subsecundum is a highly complex species consisting of numerous segregates. Its outstanding character is the arrangement of pores like a string of beads along the margins of the hyaline cells of the branch leaves. All Illinois specimens examined were very similar in character, thus no segregates are recognized.

Habitat—Sandstone creek banks, wet meadows, bogs, and wet woods.

Distribution—Clark Co.: Rocky Branch, *Pepoon s.n.* (ILLS). Cook Co.: Zander's Woods, *Mohlenbrock s.n.* (SIU). Johnson Co.: Benson's Bluff, *Snider 463* (SIU). Lake Co.: Barrington, *Steyermark 80321* (F). McHenry Co.: Ringwood, *Vasey s.n.* (F).

10. *Sphagnum girgensohnii* Russ.

Plants usually tall and robust, green to yellow or brownish; cortical cells of stem in 2-4 layers, large, thin-walled, varying in size and shape, each cell with a single, large, rounded pore in the upper end, fibril-bands lacking; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with conspicuous necks; stem leaves short-lingulate, concave, lanceolate at the broad apex, hyaline cells normally not fibrillose or porose; branch leaves normally imbricate, small, ovate, involute to the toothed apex, hyaline cells fibrillose, porose; chlorophyllose cells trapezoidal to triangular in cross-section, more broadly exposed on the inner leaf surface.

The conspicuously star-shaped capitulum and the spreading branches which are long and drooping in five rows aid in field recognition of this attractive species.

Habitat—Wet sandstone bluffs.

Distribution—LaSalle Co.: Tonti Canyon, Starved Rock State Park, *Voth & Richards s.n.* (DUKE).

11. *Sphagnum fuscum* (Schimp.) Klinggr.

Plants slender and delicate, forming large, compact hummocks, normally brown or with a brownish tinge; cortical cells of stem in 2-4 layers, large, thin-walled, lacking fibril-bands and pores; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with conspicuous necks; stem leaves lingulate, concave, hyaline cells non-porose, usually non-fibrillose; branch leaves usually spreading, narrowly lanceolate, involute towards the toothed apex, hyaline cells fibrillose,

porose; chlorophyllose cells triangular to trapezoidal in cross-section, broadly exposed on the inner leaf surface.

This hummock-forming species can be recognized in the field by its brown pigmentation, brown stem, and spreading branch leaves, although red-brown forms of *S. capillaceum* and its var. *tenellum* can be confused with it.

Habitat—Known only from Tamarack Swamp where it forms scattered hummocks around the bases of *Larix*.

Distribution—Lake Co.: Tamarack Swamp, *Hill 269* (F).

12. *Sphagnum warnstorfii* Russ.

Plants slender, delicate, green to tinged with pink to red; cortical cells of stem in 2-4 layers, large, thin-walled, lacking fibril-bands and pores; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with conspicuous necks; stem leaves lingulate to lingulate-ovate, concave, hyaline cells non-fibrillose and non-porose; branch leaves often five-ranked, spreading, lanceolate, involute to the toothed apex, hyaline cells fibrillose, on outer surface with numerous small, strongly ringed pores in upper area, pores below are larger and less strongly ringed; chlorophyllose cells triangular to trapezoidal in cross-section, broader exposure on the inner leaf surface.

This species is one of four with a reddish color. When green shoot forms are found the red branch axis can be seen through the leaves. In the field it can be recognized by the arrangement of the branch leaves in five distinct rows and curved outward when dry.

Habitat—Known only from Wauconda Bog.

Distribution—Lake Co.: Wauconda Bog, *Hill 257* (F).

13. *Sphagnum capillaceum* (Weiss) Schrank (*S. acutifolium* Ehrh.; *S. acutifolium Schimperi* Warnst.)

Plants short, compact, green generally tinged with red; cortical cells of stem in 2-4 layers, thin-walled, lacking fibril-bands and pores; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with conspicuous necks; stem leaves at least twice as long as wide, lingulate to triangular ovate, deeply concave, apex normally involute, toothed, hyaline cells with fibrils faint to lacking, pores few to absent; branch leaves imbricate to slightly spreading, normally lanceolate, involute above to the toothed apex, hyaline cells fibrillose, porose; chlorophyllose cells triangular to trapezoidal in cross-section, broader exposure on the inner leaf surface, hyaline cells slightly convex on the inner surface, strongly so on the outer.

This species and *S. tenerum* intergrade to such a high degree that at times one cannot distinguish between them. Much work is needed to clarify the differences between these two species, if, indeed, any exist. Illinois plants can nearly always be separated by the degree of fibrillosity and porosity of the hyaline cells of the stem leaves, *S. capillaceum* being faintly fibrillose and with a few pores present to entirely lacking, whereas in *S. tenerum* the hyaline cells of the stem leaves are heavily

fibrillose with numerous pores dispersed theroughout. It is when one examines specimens throughout a wide area of their range that the problem is recognized.

Habitat—Found in bogs, meadows, wet woods, swamps, and along moist sandstone bluffs.

Distribution—Clark Co.: Rocky Branch, *Vaughan 6* (F). Cook Co.: Huckleberry Bog, *Calkins 320* (F). Lake Co.: Tamarack Swamp, *Hill 256* (F). Pope Co.: Hayes Creek Canyon, *Schwegman s.n.* (SIU). Will Co.: New Lennox, *Hill s.n.* (ILL).

13a. var. *tenellum* (Schimp.) Andr. —Stem leaves more lingulate with most hyaline cells divided; branch leaves shorter, somewhat secund. Habitat same as for species.

Distribution—Lake Co.: Tamarack Swamp, *Hill 270* (F).

14. *Sphagnum tenerum* Sull. & Lesq.

Plants compact to robust, yellowish to whitish, usually tinged with pink to deep scarlet above; cortical cells of stem in 2-3 layers, large, thin-walled, lacking fibril-bands and pores; cortical cells of branches lacking fibril-bands, composed of smaller, non-porose cells and larger, porose, retort cells with conspicuous necks; stem leaves lingulate-acuminate, involute towards apex, hyaline cells fibrillose throughout or nearly so, inner surface with many large, rounded pores; branch leaves imbricate, lanceolate to ovate, somewhat involute near toothed apex; hyaline cells fibrillose, porose; chlorophyllose cells small, triangular in cross-section, exposed on the inner leaf surface; hyaline cells convex on inner surface, extremely convex on outer surface, usually one half the diameter of the cell, or more.

S. tenerum is noted for its red to scarlet color, which, however, is not always evident. See comments under *S. capillaceum*.

Habitat—Moist creek banks and sandstone bluffs.

Distribution — Pope Co.: Lusk Creek Canyon, *Bailey & Swayne 2468* (SIU). Clark Co.: *Arensi s.n.* (Duke). Randolph Co.: Piney Creek, *Skorepa s.n.* (SIU).

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Notes

THE SOUTHEASTWARD MOVEMENT OF THE WESTERN HARVEST MOUSE (*REITHRODONTOMYS megalotis*) IN ILLINOIS

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ABSTRACT. — An eastward range extension of *Reithrodontomys megalotis* into Champaign County is reported, and the Southeastward movement of this rodent in Illinois is discussed.

The most recent work showing the distribution of the western harvest mouse in Illinois is that of Hall and Kelson (1959) in which the authors indicate this mouse is confined to the extreme north-western corner of the state. Since 1959 this mouse has been trapped infrequently in northwestern and central Illinois. The last publication of a trapping record was by Birkenholz (1967). The disposition and references, and trapping locality of Illinois records are shown in Table 1 and Figure 1 respectively.

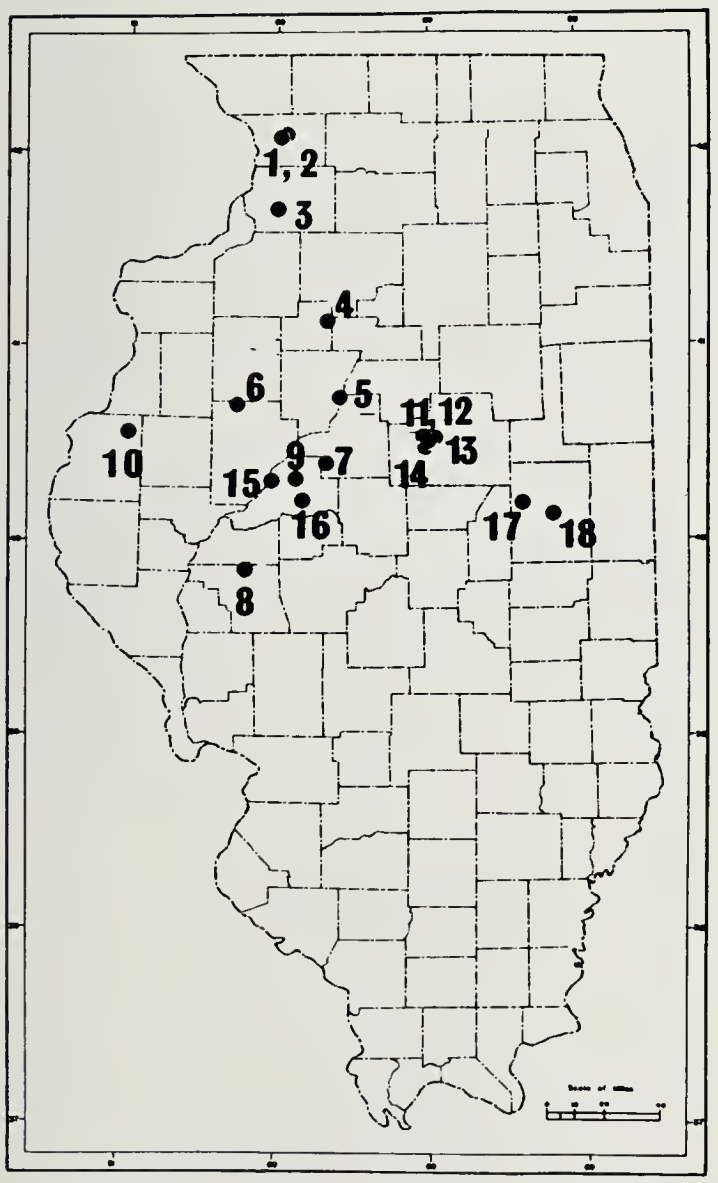

FIGURE 1. — Map of the localities at which *Reithrodontomys megalotis* has been trapped in Illinois. See Table 1 for further details.

In 1966, the senior author snap-trapped one *R. megalotis* 3 miles NE Mahomet, Illinois, in an open field with *Setaria* among the predominant grasses. An additional 400 trap nights in the field and other *Setaria* fields in the vicinity produced no additional *Reithrodontomys*. In the spring of 1969, the junior author live-trapped one *R. megalotis* in an open field in Trelease Woods, 1.5 miles E. of Urbana, Illinois, where *Sargastrum* comprised approximately 90% of the grass community, and additional 375 trap nights in the area produced no further *Reithrodontomys*.

Trelease Woods have been trapped thoroughly since 1959, and in general the area surrounding the Urbana Campus has undergone saturation trapping for at least 20 years as a part of various courses and research at the University of Illinois. The comparatively sudden appearance of *Reithrodontomys megalotis* in the trapping records of this area woud seem to indicate this rodent is extending its range. This conclusion is borne out by the fairly consistent association of chronological succession with more southward and eastward records (Table I and Map I).

That the harvest mice in Champaign County were caught in open fields and in the case of the 1969 record, in a field that is intentionally being converted to a prairie condition, appears to substantiate Birkenholz' (1967) suggestion that the harvest mouse is extending its range in Illinois in response to the clearing of forested areas with the subsequent regrowth of stands of assorted grasses.

TABLE 1. *Reithrodontomys megalotis* trapped in Illinois.

Map Number	Date	Reference	Disposition
1-2	November, 1963	Hoffmeister and Warnock, 1955	UI
3	March, 1956	Klimstra, 1957	SIU
4	August, 1958	Stains and Stuckey, 1960	SIU
5	January, 1962		EC
6	January, 1962		UI
7-8	March, 1962	Stains and Turner, 1963	SIU
9	March, 1963	Birkenholz, 1967	ISU
10	April, 1963	Birkenholz, 1967	ISU
11-14	November, 1963-65	Birkenholz, 1967	ISU
15	January, 1965		UI
16	November, 1965		UI
17	January, 1966		UI
18	April, 1969		UI

EC: Eureka College Museum
SIU: Southern Illinois University
ISU: Illinois State University
UI: University of Illinois Museum of Natural History

ACKNOWLEDGMENTS

The authors wish to thank Dr. Donald F. Hoffmeister and Dr. M. Raymond Lee for their cooperation and encouragement. Expenses were funded in part by a National Science Foundation Traineeship held by the senior author.

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Manuscript received August 5, 1969

EFFECT OF CARCINOGENS ON RAT DIAPHRAGM CARBOHYDRATE METABOLISM

LEON L. GERSHBEIN
Northwest Institute for Medical Research, Chicago

Abstract. — In the presence of high levels of the hydrocarbons diphenyl and acenaphthene or the potent carcinogen, 7, 12-dimethyl[a]benzanthracene, average differences in the oxygen and glucose uptakes and glycogen content of the rat diaphragm were not significantly altered. Incubation was carried out in a phosphate-saline medium containing 120 mg% glucose. The hepatocarcinogen, p-dimethylaminoazobenzene (1.00 mg), caused only a minor decrease in glucose utilization and N-2-fluorenylacetamide (1.00 mg) and β-naphthylamine (0.50 mg) were responsible for depressions in glycogen content; the amine at a level of 0.050 mg was without effect.

As the role of carcinogenic hydrocarbons and hepatocarcinogens in muscle metabolism is relatively unknown, a study was undertaken of the effect of such agents on the oxygen uptake, glucose utilization and glycogen turn-over of the isolated rat diaphragm.

Materials and Methods

Eastman Kodak Company was the source of the high purity agents except for acenaphthene which was obtained from Gesellschaft für Teerverwertung, Germany. The phosphate-saline medium of Stadie and Zapp (1947) employed in the incubation of hemidiaphragms, was prepared double strength; the final glucose concentration was 120 mg%. Due to their low solubility in aqueous solution, the various agents were dissolved in 1,2-propanediol, the volume added per Warburg flask being 0.20 ml; warming was required to dissolve some of them.

Male rats ranging 130-165 gm in weight at the time of experimentation were purchased from Holtzman Rat Company, Madison, Wisconsin and starved for 24 hr. They were sacrificed by swift decapitation, incised and the hemidiaphragms removed, rapidly chilled in saline and after trimming and weighing, placed in the Warburg flasks. By the present method of paired hemidiaphragms, one tissue was incubated with 1.0 ml double strength phosphate-saline medium, 0.80 ml physiological saline and 0.20 ml of propylene glycol (control) and the corresponding hemidiaphragm, with 1.0 ml medium, 0.80 ml saline and 0.20 ml of the solution containing hydrocarbon or carcinogen (treatment). Control flasks without tissue were also employed concurrently. Incubation was carried out with pure oxygen at 37.5° C for 1 hr. Glycogen was determined following alkaline hydrolysis of the hemidiaphragms and the glucose in the incubated fluids ascertained after dilution and deproteinization. The procedures for the analytical determinations as well as the preparation of tissues and the requisite calculations have been presented earlier in greater detail (Gershbein *et al.*, 1964; Gershbein, 1965).

Results and Discussion

Average differences in oxygen and glucose uptakes and glycogen content for the tissues incubated with 1.00 mg each of diphenyl, acenaphthene and 7,12-dimethyl-[a]benzanthracene, p-dimethylaminoazobenzene or butter yellow, N-2-fluorenylacetamide and 0.05 and 0.50 mg β-naphthylamine appear in Table 1. Significance of the respective differences was ascertained by the Fisher t-test.

As with the noncarcinogenic hydrocarbons, diphenyl and acenaphthene, dimethylbenzanthracene at a comparable weight level did not affect the respective differences. A small depression in glucose uptake was noted with p-dimethylaminoazobenzene to the exclusion of any effect on the Qo_2 and glucose utilization. However, marked glycogen inhibition occurred with both the fluorenylacetamide (1.0 mg) and β-naphthylamine (0.50 mg), the latter also depressing the oxygen uptake at the 1% level of probability. The naphthylamine proved ineffective when the level was reduced to 50 μg.

Although pharmacological dosages were screened, these findings are of importance in that they further delineate differences among the carcinogen types, in this instance,

TABLE 1. Average differences in Qo_2, Glucose Uptake and Glycogen Content of Diaphragms Incubated with Hydrocarbons and Carcinogens[a,b]

Agent (mg)	Mean $Q0_2$ Difference		Mean Glucose Difference[c]		Mean Glucose Difference	
	μl/mg wet tissue/hr	t	μg/mg wet tissue/hr	t	μg/mg wet tissue/hr	t
7,12-Dimethyl[a]benzanthracene (1.00)	0.03 ± 0.044 (9)	0.60	−0.02 ± 0.139 (10)	0.13	0.10 ± 0.057 (12)	1.69
Diphenyl (1.00)	0.17 ± 0.254 (16)	0.66	−0.59 ± 0.555 (15)	1.06	0.07 ± 0.050 (17)	1.46
Acenaphthene (1.00)	0.00 ± 0.036 (10)	0.04	−0.11 ± 0.525 (11)	0.22	0.03 ± 0.053 (11)	0.54
N-2-Fluorenylacetamide (1.00)	0.08 ± 0.069 (17)	1.10	1.47 ± 0.864 (15)	1.70	0.14 ± 0.045 (17)	3.00*
p-Dimethylaminoazobenzene (1.00)	0.05 ± 0.062 (17)	0.79	1.81 ± 0.846 (16)	2.14*	−0.03 ± 0.032 (17)	0.83
β-Naphthylamine (0.050)	−0.01 ± 0.041 (11)	0.24	0.43 ± 0.225 (9)	1.92	0.04 ± 0.056 (11)	0.77
β-Naphthylamine (0.50)	0.17 ± 0.041 (20)	4.14**	0.53 ± 0.310 (16)	1.69	0.25 ± 0.045 (19)	5.60**

[a] The means (± S.E.) are deduced from the specific number of paired hemidiaphragms given in the parentheses.
[b] A positive mean difference indicates a decrease in response in the presence of the test agent.
[c] The extent of glucose utilization was based on the final concentration of the respective media incubated without diaphragm.
** $P < 0.01$.
* $P < 0.05$.

by the criterion of rat diaphragm metabolism. Preincubation of hemidiaphragms in media containing such agents as well as the determination of the combined effect of carcinogen and insulin on the isolated rat diaphragm would be of great interest, experiments of which are not included in the present report.

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Manuscript received August 5, 1969

DR. CALVIN MIDGLEY

Last summer, Dr. Calvin P. Midgley taught a short course of chemistry at the Condell Memorial Hospital, Libertyville. He emphasized understanding rather than memorization. Dr. Midgley has patented a portable chemistry set which is used to introduce a chemical principle and present an experimental demonstration simultaneously. His approach emphasizes the qualitative concepts, reserving the quantitative concepts until the student has attained an appreciation of the science. He introduced a similar course at Mundelein College where he had taught for seven years. In addition to classroom teaching, he has authored a series of books beginning at the sixth grade level. Dr. Midgley has published in the *Transactions* some aspects of his approach as applied to elementary school pupils. *—Dr. Boris Musulin, Department of Chemistry, Southern Illinois University, Carbondale, Illinois, 62901.*

Manuscript received May 8, 1970

DR. JOHN BARDEEN

Dr. John Bardeen, Nobel Laureate and long-time member of the Illinois State Academy of Science, was awarded honorary membership in the Wisconsin Academy of Sciences, Arts and Letters during their Centennial Celebration on May 9, 1970. In addition to the Nobel prize in Physics in 1956 for basic work on the transistor, he was awarded the United States National Medal of Science in 1966 and an honorary Doctor of Science degree from the University of Wisconsin in 1960. Dr. Bardeen has been Professor of Physics and Electrical Engineering at the University of Illinois since 1951. —*Dr. Boris Musulin, Department of Chemistry, Southern Illinois University, Carbondale, Illinois, 62901.*

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REPRODUCTIVE AND DEVELOPMENTAL DIFFERENTIATION WITHIN SECTION PRIMIGENIA OF THE GENUS CLARKIA

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ABSTRACT.—Section Primigenia consists of three subsections. Five diploids are contained in two of these and the third consists of a single allotetraploid. Diploids of different subsections are separated genetically by numerous and extremely well developed isolating mechanisms. Those within the same subsection are not so well isolated from each other. Various lines of evidence indicate that the allotetraploid has combined features and genomes of the two diploid subsections. Such well developed isolating mechanisms have apparently set the stage for natural polyploidy which seems to knit the entire genus.

The genus *Clarkia* is a close relative of the well known *Oenothera* and this is indeed evident in their chromosomal systems. *Clarkia* has 36 species, 24 of which are diploids and the rest are allotetraploids. Most of the species are indigenous to California. The species are annual and occur in separate colonies that vary in size (Lewis and Lewis, 1955). The gene pools of the diploid species are without exception separated by strong barriers to gene exchange. Some species cannot be crossed to one another; interspecific hybrids that can be produced are usually sterile. Such sterility is invariably associated with extensive structural rearrangement of the chromosomes, with or without a change in basic number (Lewis, 1953a).

In the course of their evolution, the diploid species taken as a whole, have become adapted to a diversity of habitats within the plant communities that represent modern derivatives of the Madro-Tertiary Geoflora (Lewis, 1953b). There is a strong correlation between habitat preference and phylogenetic sequence. The derivative species occupy more xeric and presumably more recent habitats than their progenitors (Lewis, 1953b). The pattern of relationships within the genus is one of diverse lineages, and the species have sometimes been referred to separate genera. Natural polyploidy serves to knit the entire group together (Lewis and Lewis, 1955).

The genus is subdivided into 10 sections, of which Primigenis seems to be the oldest (Lewis and Lewis,

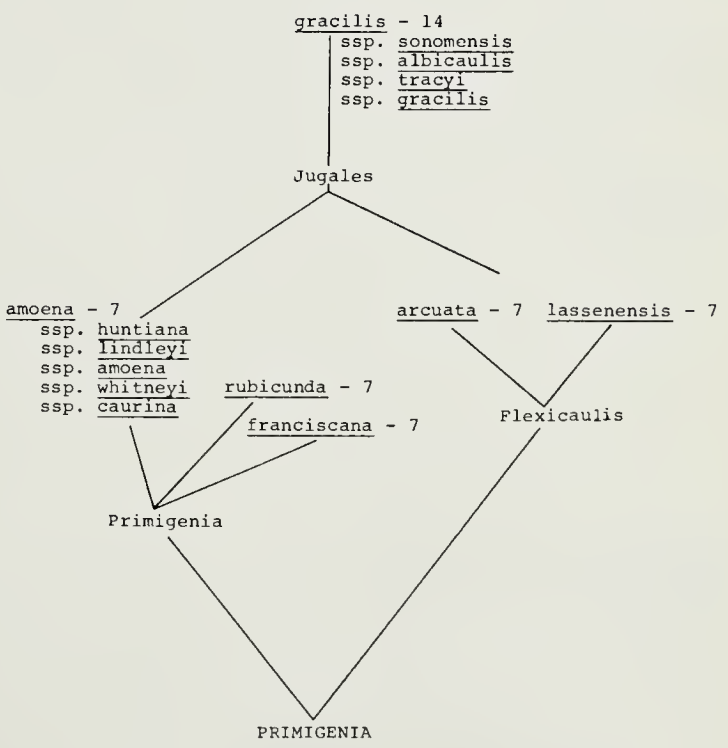

FIGURE 1. Inferred phylogenetic relationships in section Primigenia.

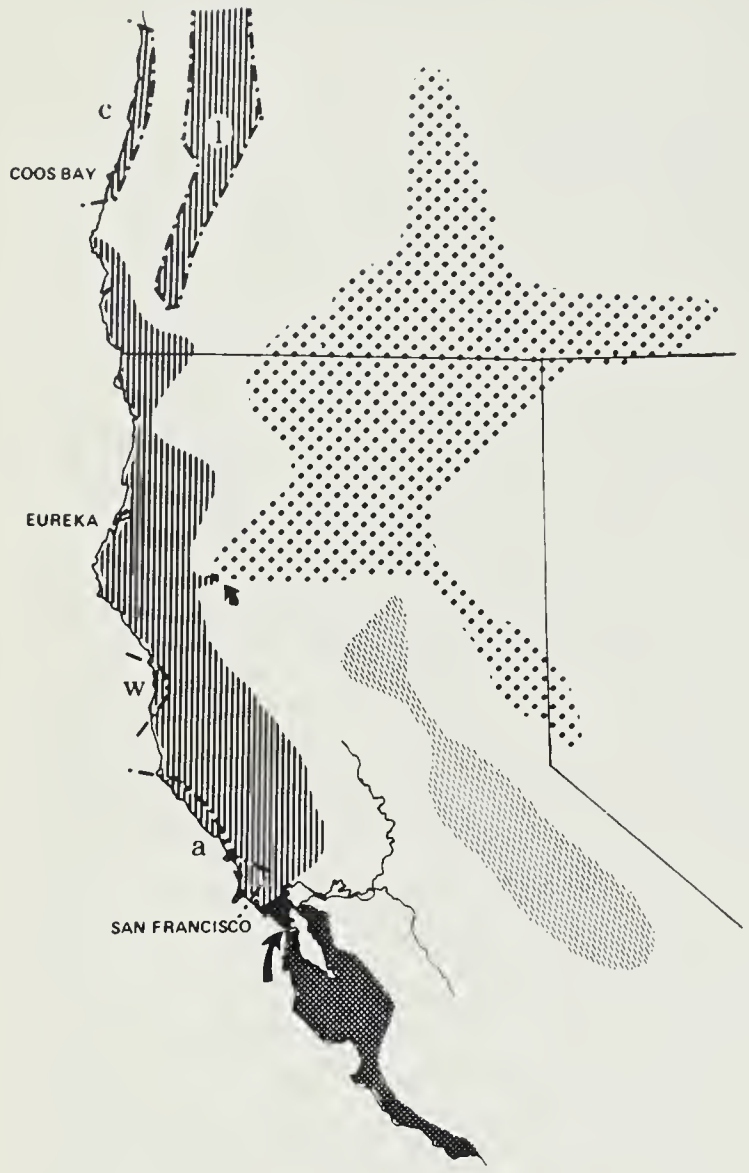

FIGURE 2. Distribution in northern California and adjacent parts of Nevada and Oregon of the five diploids in the section Primigenia. The third subsection, Jugales, is composed of a single polytypic species whose four subspecies overlap the distribution of the five diploids (see, Lewis and Lewis, 1955; Abdel-Hameed, 1967).

subsection Primigenia

c. am. huntiana

a *amoena*

w *whitneyi*

c *caurina*

l *lindleyi*

C. rubicunda

C. franciscana

subsection Flexicaulis

C. lassenensis

C. arcuata

1955). Section Primigenia includes 6 species grouped into three different subsections (Figure 1). Primigenia and Flexicaulis subsections contain 5 diploids some of which are considered to be the most primitive members of the genus (Lewis and Lewis, 1955). The third subsection, i.e. Jugales, consists of an allotetraploid that combines morphological and ecological features of the other two subsections; its range overlaps that of the other five species (Figure 2). The purpose of the present study is to examine the extent of reproductive and developmental differentiation between species of these three subsections.

Materials and Methods

Bulk collections of seeds were made from wild populations by combining the seeds from a number of capsules collected at random, one from each plant.

Plants were grown from these seeds in 5 inch plastic pots containing a uniform soil mix consisting of 2 parts sandy loam :1 part peat moss. They were occasionally fertilized during the growing season.

The pollination procedure varied according to the breeding habit. Self-pollination did not require emasculation; cross-pollination, however, required emasculation of the female parent. Emasculation was practiced when the stigma lobes were still closed and the anthers had not yet shed their pollen. Pollinations were done when the stigma became receptive. The flowers were protected from unwanted pollen by covering them with cellophane peanut bags. Bags were removed after fertilization had occurred.

TABLE 1.—Intra- and Interspecific Hybrids Between Representative Taxa in Section Primigenia.

	Number of Crosses	Number of Plants	Average Percentage of Stainable Pollen ± Standard Error
I. Intra-subspecific Hybrids:			
A. ♀ *C. g. sonomensis* x ♂ *C. g. sonomensis*	11	23	77.3 ± 8.04
B. ♀ *C. g. tracyi* x ♂ *C. g. tracyi*	3	9	86.3 ± 9.78
C. ♀ *C. g. gracilis* x ♂ *C. g. gracilis*	2	2	88.2 ± 8.47
Subtotal	16	34	83.9 ± 8.76
II. Inter-subspecific Hybrids:			
A. ♀ *C. g. tracyi* x ♂ *C. g. albicaulis*	4	10	77.0 ± 9.23
B. ♀ *C. g. sonomensis* x ♂ *C. g. albicaulis*	2	4	33.3 ± 4.68
C. ♀ *C. g. sonomensis* x ♂ *C. g. tracyi*	3	9	75.0 ± 7.63
D. ♀ *C. g. tracyi* x ♂ *C. g. sonomensis*	3	7	62.2 ± 8.31
E. ♀ *C. g. albicaulis* x ♂ *C. g. sonomensis*	2	2	38.7 ± 5.64
F. ♀ *C. g. sonomensis* x ♂ *C. g. gracilis*	8	20	70.0 ± 9.26
G. ♀ *C. g. gracilis* x ♂ *C. g. sonomensis*	5	5	65.8 ± 6.73
H. ♀ *C. g. gracilis* x ♂ *C. g. tracyi*	2	6	62.3 ± 8.34
I. ♀ *C. g. tracyi* x ♂ (*sonomensis* x *gracilis*)	1	3	75.0 ± 7.67
Subtotal	30	66	62.1 ± 7.50
III. Triploids with *C. amoena huntiana*:			
A. ♀ *C. g. sonomensis* x ♂ *C. am. huntiana*	32	98	9.5 ± 0.62
B. ♀ *C. am. huntiana* x ♂ *C. g. albicaulis*	1	1	2.8 ± 0.31
C. ♀ *C. g. tracyi* x ♂ *C. am. huntiana*	19	57	5.0 ± 0.47
D. ♀ *C. am. huntiana* x ♂ *C. g. gracilis*	10	30	4.7 ± 0.86
Subtotal	62	176	5.5 ± 0.57
IV. Triploids with *C. lassenensis*:			
A. ♀ *C. g. sonomensis* x ♂ *C. lassenensis*	1	3	3.0 ± 0.42
B. ♀ *C. g. tracyi* x ♂ *C. lassenensis*	2	3	2.5 ± 0.57
C. ♀ *C. g. gracilis* x ♂ *C. lassenensis*	2	5	1.5 ± 1.21
Subtotal	5	11	2.3 ± 0.73
V. F_1 diploid-hybrids between *C. amoena huntiana* and *C. lassenensis*:			
A. ♀ *C. am. huntiana* x ♂ *C. lassenensis*	5	23	2.5 ± 0.93
B. ♀ *C. lassenensis* x ♂ *C. am. huntiana*	2	2	1.1 ± 0.45
Subtotal	7	25	1.8 ± 0.69

A total of 120 crosses between certain taxa that are representative of all three subsections of the section Primigenia were carried out in the greenhouse (Table 1, Figure 3). The reason why other taxa in this section were not represented, lies in the fact that the majority of such remaining crosses were sporadically made by different investigators and their results as well as mine will be discussed jointly in some detail in a later section of this paper.

Pollen viability was estimated from counts of pollen grains which stained with cotton blue in lacto-

phenol. Only well stained and normal shaped grains were considered viable, and calculations were based on a total of at least 200 pollen grains counted.

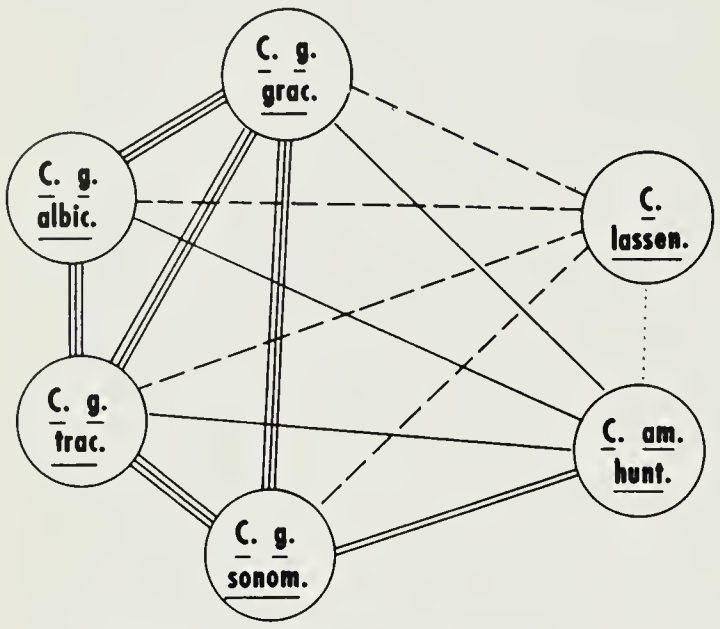

FIGURE 3. Polygon showing inferred crossing relationships from greenhouse progenies.

. . . . . Rarely set seeds; developmental abnormalities in most progenies; few plants reach maturity and are extremely low in fertility.

- - - - - - - - Rarely set seeds; developmental abnormalities in some progenies; most flower buds are low in fertility.

——— Relatively high seed set; normal progeny; almost all reach maturity, but show variable degrees of fertility.

═══ Relatively high seed set; normal progeny; progenies are relatively fertile.

═══ Abundant seed set; normal progenies with normal fertility.

Buds for cytological study were fixed in 1:3 acetic-alcohol for at least 24 hours, then changed to 70% alcohol and stored in the refrigerator. They were stained in bulk using alcoholic-HCl carmine (Snow, 1963), which gave the most satisfactory results. From these buds slides were prepared by squashing 2-4 anthers after gentile heating in a drop of 45% acetic acid. Some slides were made permanent using dry ice or liquid nitrogen. After freezing the slide, the cover slip was pried off with a razor blade and the slide was immersed in two changes of absolute alcohol for at least 5 minutes. A drop of euparal and a clean cover slip was placed on the location of the previous cover slip.

Results and Discussion

In order to better understand the mode of evolution within section Primigenia, it becomes necessary to assess the extent of reproductive and developmental differentiation between various species in the section. In addition, observations pertaining to their morphological, eco-geographical, cytological and chemotaxonomical relationships are usually considered in such a study. Thus, data on crosses between different taxa of the section as well as other types of evidence are required. The present study shows the results of interspecific hybridization between some of the species of this section (Table 1, and Figure 3). Of these, hybridization between the diploids *C. amoena* ssp. *huntiana* and *C. lassenensis* proved to be the most difficult due to the presence of a number of barriers to gene exchange between their respective gene pools. These two diploids showed a diversity in their reproductive and developmental patterns, whose magnitude is characteristic of fairly distantly related species or higher taxonomic groupings. By comparison, the phylogenetic relationship between *C. lassenensis* and the tetraploid *C.*

gracilis appeared closer. *C. amoena* ssp. *huntiana* and *C. gracilis* represented the closest relationship of all as witnessed by the ease of hybrid production and their normal pattern of development.

Both prezygotic and postzygotic types of isolation were observed, especially during the formation of the F_1 diploid hybrids. Crosses between *C. amoena* ssp. *huntiana* and *C. lassenensis* proved generally quite unsuccessful. Since most crosses failed to set seeds, it is probable that such failure was due to the inability of the pollen to effect fertilization. In nature, however, the production of these hybrids apparently involved several isolating mechanisms. Acting together, they are extremely efficient in isolating the gene pools of both diploids. The major part of such isolation was due to prezygotic mechanisms, especially spatial, seasonal, and floral isolation.

Spatial isolation of the two diploids, *C. amoena* ssp. *huntiana* and *C. lassenensis* (Figure 2), prevents any sympatric association between them. Such spatial isolation would be reinforced by ecogeographical differences. The single sympatric population discovered in early June, 1966 was located outside the known distributions of both diploids, in the area where both appear closest to each other (small arrow, Figure 2). Should more favorable environmental conditions prevail, more sympatric associations might occur. Notice that species of subsection Primigenia are westerly distributed and close to the Pacific coast line, while those that belong to subsection Flexicaulis are distributed inland and close to the Sierra Mountains range (Figure 2). Furthermore, the two diploid subsections are well separated ecogeographically except for this mixed population which represent the only recorded case of sympatric association between any two diploid species of these two subsections.

Seasonal isolation was observed in both greenhouse and wild plants, as *C. lassenensis* was about three or four weeks earlier in starting and ending its flowering season than *C. amoena* ssp. *huntiana*. The sympatric population showed clearly that seasonal variation to a large extent isolated the two diploid gene pools. However, the short period of overlap would be sufficient for cross-pollination. In this population, a relatively large number of pollinating insects such as honey bees, bumble bees, bee flies and several different butterflies, were observed to move from one plant to another. Under such conditions, natural cross pollination could occur, but extensive cytological examination revealed no interspecific hybrids in this mixed colony.

All *Clarkia* species are self-compatible (Lewis, 1953a) and are visited by various kinds of bees, which are undoubtedly the principal pollinators of the genus (Lewis and Lewis, 1955). They all seem to lack heterostyly and various mechanisms of incompatibility between pollen tube and style. However, some of the latter may be operative in interspecific hybridization but this is not known. The flowers of most species are protandrous, and the mature stigma is held above the stamens. Outcrossing is certainly promoted in these species even though they

are self-compatible. But some taxa such as *C. gracilis* ssp. *gracilis* have cleistogamous flowers and are primarily or exclusively self-pollinated. Various intermediate degrees of self-pollination also occur (Lewis, 1953a). Even though every species of *Clarkia* is sympatric with at least one other species over part of its distribution range, no naturally occurring interspecific diploid hybrids have been found (Lewis and Lewis, 1955). Nevertheless, hybridization obviously does occur at least on rare occasions inasmuch as some of the alloploid species have been derived from normally self-pollinating species (Lewis and Lewis, 1955).

Morphological observations revealed that *C. lassenensis* was predominantly an inbreeder as the stigma was usually located at the same level or lower than the anthers, whereas *C. amoena* ssp. *huntiana* is predominantly an outbreedr as its sigma is situated higher than the anthers. Such a difference in floral structure might prevent cross-pollination between the two species, or would at least greatly restrict its occurrence. The western populations of *C. lassenensis* have relatively large flowers with a stigma which often is higher than the anthers; it is probably only in this western area where hybridization might occur in nature. All prezygotic mechanisms mentioned above have played a major role in quite effectively isolating the two diploid gene pools.

Postzygotic mechanisms have also played a significant role in the differentiation and diversity observed at present in both taxa. By definition, these mechanisms work after fertilization has taken place and the hybrid zygotes formed are rendered inviable or produce only weak or sterile hybrids. Postzygotic isolation is usually expressed by three different mechanisms: the inviability or weakness of the F_1 hybrid itself, the complete or partial sterility of vigorous F_1 hybrids, and the production of many weak or sterile F_2 progeny by vigorous fertile F_1 hybrids (Stebbins, 1966). The action of all of them can be characterized in a general fashion as the inability of the parental genes to work together properly in the cells of the hybrid or its progeny or the so-called genic disharmony (Stebbins, 1966). Almost all seed capsules collected from the F_1 diploid hybrid plants contained light-colored chaff which represented aborted ovules or failure of fertilization. A very few had a small number of completely shrivelled or normally appearing seeds, of which some of the latter succeeded in germinating. The completely shriveled brown ones had virtually nothing inside or had ovules which had been fertilized but whose subsequent development was impaired. The partially shriveled brown seeds usually contained a small embryo and/or a small endosperm. Some lacked endosperm tissue.

Hybrid inviability or weakness was observed as a strong isolating mechanism that led to early seedling death. Germination of F_1 hybrid seeds was usually one to two weeks later than normal diploid or tetraploid seeds. F_1 seedlings were also slower in growth than normal ones due to slow differentiation of the hypocotyl and epicotyl. These seedling showed various degrees of

abnormal development, witnessed by irregular swelling of the epicotyl below the cotyledons. In a few cases, the cotyledons showed abnormal and irregular development and some were fused together with very little or no apical meristematic tissues. In fact, some of them covered or engulfed completely the apex during their irregular differentiation. Some F_1 seedlings that were capable of producing true leaves showed various late developmental abnormalities affecting the leaves and stems.

Developmental or genic hybrid sterility which is usually rare in plants (Stebbins, 1966) was observed in a few of those F_1 seedlings that succeeded in growing beyond the above mentioned phases. They showed irregularities during their floral differentiation. Generally, all F_1 diploid hybrids were quite sterile due to abnormal development of male and female gametophytes and/or meiotic breakdown. In many cases, they bore relatively small sized and abortive flowers, of which some developed all or in part abnormally. The irregularities observed included flowers which had more than or less than the normal four petals, eight anthers, and four-lobed stigma. Certain cases provided evidence for reversion of development of at least one anther into an extra petal. These floral irregularities were in low frequency, most flowers showing normal development, but all flowers were of extremely low fertility.

Segregational hybrid sterility is caused by abnormal segregation at first anaphase of whole chromosomes or chromosome segments . The unbalanced gametes resulting are usually inviable and probably represent the principal factor of the extremely low fertility observed in F_1 diploid hybrids. Most M_I plates of these hybrids had 14 unpaired chromosomes. Upon doubling the chromosome number of plants with normal flower development, normal chromosome segregation and fertility were restored.

F_2 hybrid breakdown was observed in the progeny of selfed F_1 plants. Another group of plants that showed what might be termed F_2 breakdown was the hybrid progeny of crosses between F_1 diploid hybrids and natural allotetraploids. The majority of these crosses had a better seed setting than their F_1 parents. Most seeds germinated to produce healthy and vigorous plants. However, all of them except two, were quite sterile and did not set seeds upon selfing or further crossing. Probably the main factor causing their infertility was irregular meiotic chromosome orientation and segregation, since most of their PMCs showed a majority of univalent formation on M_I plates.

It is obvious that the two diploid taxa *C. amoena* ssp. *huntiana* and *C. lassenensis* representing subsections Primigenia and Flexicaulis, are separated by a multitude of strong isolating mechanisms. Such well developed genetic barriers have probably set the stage for a relatively high ratio of allotetraploids which comprise 1/3 of the species in this genus (Lewis 1953a; Lewis and Lewis, 1955). F_1 hybrids between these two diploids manifested different barriers to gene exchange in a variety of developmental abnormalities that could be classified into those affecting vegetative structures as opposed to those affecting repro-

ductive structures. In general, the majority of postzygotic isolating mechanisms are probably the end product of either disharmonious gene action between parental genomes in the hybrid and/or abnormal segregation of parental chromosomes.

Developmental abnormalities and reproductive isolation were at maximum between the two diploids and at minimum between *C. amoena* ssp. *huntiana* and the tetraploid *C. gracilis* ssp. *sonomensis* (see Figures 3, 4). The present data suggesting

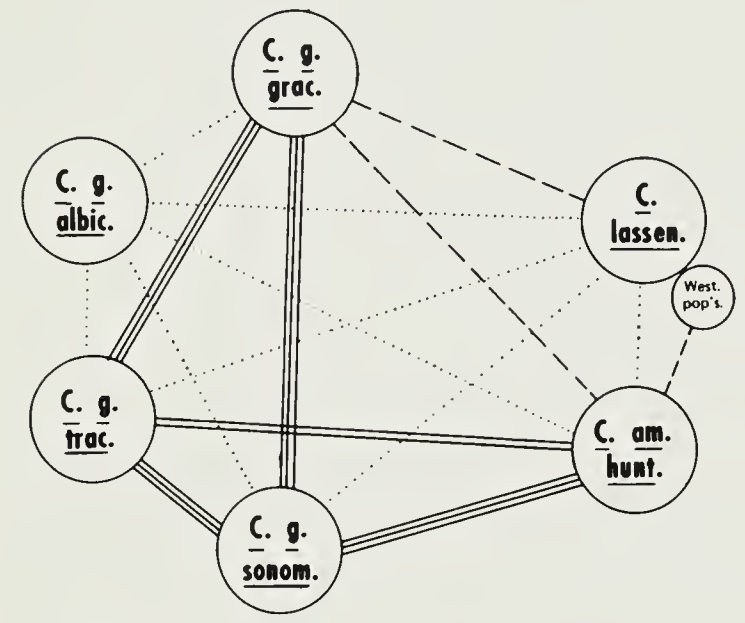

FIGURE 4. Polygon showing inferred relationships from sympatric and allopatric associations in nature.

. . . . . No gene flow.

- - - - - - - - Very little gene flow.

═══ Some gene flow occurs.

═══ Possibility for considerable gene flow.

a closer phylogenetic relationship between the latter two taxa is also supported by frequent sympatry between them in certain mixed populations where it is difficult to differentiate the two morphologically. Such observations may indicate a continuous gene flow between the two, hence, enlarging the gene pool of each and probably serving to retain close homology between their genomes (Abdel-Hameed, 1967). Evidence has accumulated recently which indicates a much higher frequency of natural hybridization and intergenome connections on the same ploidy-level (Zohary and Feldman, 1962) or on different ploidy-levels (Anderson, 1953) than was earlier realized.

Interestingly, *C. amoena* which is considered the oldest and most primitive member of the genus (Lewis and Lewis, 1955), when crossed with *C. arcuata* (the other member of subsection Flexicaulis, see Figure 1) yields few diploid hybrids. These produced very small plants that gave no flower buds with meiotic stages (Hakansson, 1946). Thus, inferring an even greater genetic isolation than that observed between *C. lassenensis* and *C. amoena.* In other words, the two diploid subsections, Primigenia and Flexicaulis are definitely well separated by strong barriers to gene exchange. Within the same subsection, genetic isolation between species seems much weaker than that observed between those of different subsections as witnessed by the relative ease of producing F_1 diploid hybrids between any two species in subsection Primigenia i.e., *C. amoena, C. rubicunda,* and *C. franciscana* (Lewis and Raven, 1958). Furthermore, Lewis and Raven (1958) concluded that *C. franciscana* is chromosomally more similar to *C. rubicunda* than to *C. amoena,* and *C. rubicunda* is probably more similar to *C. amoena* than to *C. franciscana.* They also concluded that *C. rubicunda* is probably the parent of *C. franciscana* while

the much older *C. amoena* is perhaps ancestral to both. Such parent to offspring phylogenetic relationship is apparently the case throughout the genus (Lewis, 1962).

The fact that *C. amoena* and *C. lassenensis,* which are presumably fairly closely related, show a magnitude of isolating mechanisms commonly observed in crosses of different genera or even higher taxonomic groupings, is not surprising because of the genetic diversity of the genus *Clarkia.* Lewis and Lewis (1955) lucidly illustrated that barriers to gene exchange between many *Clarkia* species are extremely well developed. They made several thousand interspecific pollinations involving at least 202 species combinations. Of these only 55 combinations produced viable hybrids. Additional crosses have been made by several other workers. The vast majority of interspecific hybrids that were produced showed a great reduction in fertility. The basis of this low fertility in interspecific hybrids in *Clarkia* lies primarily in the extensive structural rearrangement of the chromosomes of most species resulting in highly irregular meiotic behavior of the hybrids (Lewis 1953a; Lewis and Lewis, 1955; Lewis and Raven, 1958). The highly irregular meiotic behavior and the lack of homology between parental chromosomes observed in F_1 diploid hybrids between *C. amoena* ssp. *huntiana* and *C. lassenensis* (Abdel-Hameed, 1967), indicate a karyotype diversity between relatively two close species that could happen only if we assume extensive rearrangement within their respective genomes. Such observations have led Lewis and Raven (1958) to conclude that the accumulation of structural rearrangements, primarily reciprocal translocations, has undoubtedly played a major role in the formation of barriers to gene exchange and hence to speciation on the diploid level in *Clarkia.* At the same time, such well developed isolating mechanisms have set the stage for instantaneous speciation on the polyploid level through alloploidy. In other words, the principal consequences of interspecific hybridization in such a group of species would seem to be the production of a number of allopolyploid species (Lewis, 1953a). This is evident in section Primigenia since morphological, ecological, cytological and chromatographic comparisons illustrate the fact that the allotetraploid *C. gracilis* does indeed combine features and genomes of the two diploid subsections (Abdel-Hameed, 1967).

The appearance of strong and effective genetic isolation, especially so, on the diploid level between otherwise fairly closely related species, is also correlated with a characteristic mode of speciation. The mode of speciation in the section Primigenia has been apparently dependent on two major factors, i.e., rapid speciation and catastrophic selection.

Rapid speciation (as defined by Lewis, 1953a) refers to the process whereby certain natural populations of *Clarkia* differentiate reproductively from each other within a few generations to a point where they become genetically isolated. These genetically isolated populations are probably short lived, but a few may become successful species. Such a characteristic pattern of evolution

in *Clarkia* is not only rapid but seems to occur with great frequency (Lewis, 1953a). Lewis (1953a) argued that while gradual segregation of geographic races also occurs, the success of the genus seems not to lie so much in the gradual segregation of adaptive races as in the production of a multiplicity of locally adapted, genetically isolated and often ephemeral segregates. The colonial habit probably has been a factor in rapid differentiation as a result of random fixation due to reduction of population size and inbreeding, particularly in the initial stages of colony formation. Five years later, Lewis and Raven (1958) presented more evidence to support Lewis's original hypothesis of rapid evolution in *Clarkia*. They proposed that *C. franciscana* had its origin *in situ* from *C. rubicunda* (both are members of subsection Primigenia, see Figure 1) as a consequence of rapid reorganization of the chromosomes due to a temporary presence of a mutator genotype conducive to extensive chromosome breakage. Interestingly, *C. franciscana* is known from a single population in nature (in the Presidio at San Francisco, California — see large curved arrow in Figure 2). A similar mode of origin by such a rapid chromosomal reorganization was suggested in other species of *Clarkia,* i.e., *C. lingulata* from *C. biloba* (Lewis and Roberts, 1956) and *C. exilis* from *C. unguiculata* (Vasek, 1958). In all these examples, the derivative populations grow adjacent to the parental species, which they resemble closely in morphology, but from which they are reproductively isolated because of multiple structural differences in their chromosomes. The spatial relationship in each parental species and its derivative suggests that differentiation has been recent. The repeated occurrence of the same pattern of differentiation in *Clarkia* has led Lewis and Raven (1958) to suggest that this pattern of rapid reorganization of chromosomes has been an important mode of evolution in the genus.

Catastrophic selection is a process whereby an entire population is suddenly eliminated by an environmental extreme or stress, except for one or a few individuals which are exceptionally well adapted to the new environment and able to pass through the bottleneck. Such a pattern of selection would provide the conditions necessary for the establishment of a population characterized by deviant genomes. By elimination of the parental population, catastrophic selection would isolate the survivors and their progenies in an open habitat to which they are adapted. Favorable alleles improving fertility would accumulate and provide more stable and balanced genomes genetically isolated from the parental population. Lewis (1962) provided evidence for catastrophic selection in *Clarkia* based on the observation that ecologically marginal populations in several species have suddenly become extinct. Extinction in all cases resulted from exceptional drought, which throughout the history of the genus has been the most likely cause of catastrophic selection associated with speciation. He concluded also that species pairs in *Clarkia* are related as parent to offspring rather than as siblings.

Summary and Conclusion

In section Primigenia, diploids of different subsections are well differentiated reproductively and developmentally as witnessed by a multitude of strong pre- and postzygotic isolating mechanisms. Whereas diploids of the same subsection are not so well isolated genetically. Such well developed gentic isolation between the gene pools of subsections Primigenia and Flexicaulis has apparently set the stage for polyploidy. The fact that the third subsection, i.e., Jugales, consists of a single allotetraploid that combines morphological, ecogeographical, cytological and chemotaxonomical features of both diploid subsections, is quite interesting. It does not only sustain the idea that polyploidy is the by-product of such well developed isolating mechanisms, but also that polyploidy seems to knit the six species designated in Figure 1 into one group of fairly close relatives that we recognize as section Primigenia. On the other hand, the appearance of genetic isolation whose magnitude is common only between different genera or families to otherwise fairly close relatives like *C. amoena* ssp. *huntiana* and *C. lassenensis* is apparently correlated with a characteristic mode of speciation for this group.

The classical mode of evolution through the slow and stepwise accumulation of point mutations resulting in race formation and ultimately in genetic and/or geographical isolation is indeed involved. The recent accumulated evidence (Lewis, 1953a, Lewis and Raven, 1958) strongly indicate that speciation in section Primigenia and in *Clarkia* in general is for the most part a rapid process. Such a rapid process, i.e., occurring within few generations is achieved on the same ploidy level through extensive and short term chromosomal reorganization or through catastrophic selection. It may also result in a change of the ploidy level as witnessed in the instantaneous speciation of the allotetraploids that constitute 1/3 of the species in the genus. In both cases the process of speciation occurs *in situ* and the resulting species are related as offspring rather than as siblings.

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FOOD HABITS OF THE RED FOX *(VULPES FULVA)* IN UNION COUNTY, ILLINOIS

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ABSTRACT.—A study was conducted to determine the food habits of the red fox in Union County, Illinois. A total of 183 fox stomachs examined showed a variety of food items utilized. Mammalian foods constituted the principal material in the diet of this predator.

Food habits of the red fox (*Vulpes fulva*) have been investigated in detail in New York (Cook and Hamilton, 1944), Pennsylvania (English and Bennett, 1942), Michigan (Murie, 1936), Iowa (Scott and Klimstra, 1955; Scott, 1943 and 1947), and Missouri (Korschgen, 1957). Less comprehensive studies have been conducted in Wisconsin (Richards and Hine, 1953), Minnesota (Hatfield, 1939), Ohio (Gier and Gale, 1946), and Kentucky (Barbour and Gale, 1955). Although the red fox is a common and both economically and aesthetically important species in Illinois, its dietary patterns here have not been adequately investigated. This was the object of the present study.

MATERIALS AND METHODS

Stomachs used were collected by the Cooperative Wildlife Research Laboratory of Southern Illinois University in Union County, Illinois, over a period of 11 years, from March, 1956, to March, 1967. Union County, located in extreme southwestern Illinois, lies within the Southern physiographic region as described by King and Winters (1952). The most distinctive feature of this region is the range of hills in the Ozark ridge which is an extension of the Ozark highlands of Missouri and Arkansas. The hills extend across southern Illinois from east to west and encompass most of Union County. This physiographic region is the most extensively forested area in the state with 26 per cent of the area in forest — primarily of mixed oaks and hickories. Union County has 38 per cent of its area in forest cover (King and Winter, 1952). Agricultural practices in this region are classified as general farming and fruit growing; of the farmable land in Union County, 36 per cent is in pasture (includes woodland pastures), 19 per cent in corn, 13 per cent in idle land, 12 per cent in hay, with the remaining farming land devoted to soybean, grains, and other crops (Ross and Case, 1956). Union County is also a major center of fruit production in southern Illinois.

A total of 183 red fox stomachs were examined of which 13 were empty or otherwise unproductive of data. Stomach contents were initially preserved in a 10 per cent formalin solution. The analysis of materials followed standard food habit procedures. Contents of stom-

achs were placed in a fine sieve and rinsed with water. After washed materials were placed on absorbent paper towels to remove excess water, samples were weighed to the nearest 0.1 g; volume, to the nearest 0.1 ml, was then determined by water displacement in a graduated cylinder. Weights and volumes of each food item were recorded on special food habit data cards; items of less than 0.1 g, 0.1 ml, or 0.1 per cent by volume were designated as trace items (T). Percentage calculations were made for occurrence, weight, and volume of foods; per cent weight showed no significant differences from per cent volume and was excluded from final analyses.

Results and Discussion

Examination of stomach contents suggested that a variety of food items is utilized by the red fox; 59 animal, 30 plant, and 4 miscellaneous dietary items were identified (Table 1). Animal materials represented the highest percentage of food utilized, constituting 98.8 per cent by frequency of occurrence and 81.2 per cent by volume. Plant foods were found in similar frequency but yielded only 18.6 per cent of the total volume. Only 11 animal foods and 5 plant foods represented volumetrically 1.0 per cent or more of the diet. Occurrences of such items as lead shot, stones, and aluminum foil were considered accidental.

Animal Foods

Mammalian foods constituted the principal materials in the diet of the red fox, appearing in 95.0 per cent of the stomachs examined and contributing 67.1 per cent of the total volume. The cottontail rabbit was the single most important prey item (Table 1). It was also shown to be the principal food of the red fox in Iowa (Scott, 1943 and 1947), Michigan (Murie, 1936), and Missouri (Korschgen, 1957).

The prairie vole represented the second ranking mammalian food; it was recorded in 20.6 per cent of the stomachs and yielded a volume of 15.2 per cent. Deer mice, although an important mammalian food, were found less frequently and contributed less bulk to the diet of the red fox than the prairie vole (Table 1). Hoffmeister and Mohr (1957), however, reported both the prairie vole and deer mice, especially *Peromyscus leucopus,* abundant in Illinois. Higher proportions of voles to deer mice in the diet of red foxes have been documented. Scott (1943) demonstrated that even when deer mice were more abundant than prairie voles, foxes consumed more of the latter. Scott believed that preference for voles over deer mice plus differences in the daily rhythmic nature of these species might be important in accounting for differential consumption of these foods. Evidence from Scott and Klimstra (1955) showed that red fox pups preferred prairie voles to deer mice. Murie (1936) suspected that ease of capture and a more vulnerable habitat were important in the higher use of voles.

Raccoons were found to be a significant dietary item of the red fox in this study (Table 1). Scott (1943 and 1950), Scott and Klimstra (1955), and Korschgen (1957) reported finding raccoon remains in

TABLE 1.—Stomach contents of 170 red foxes collected in Union County, Illinois, 1956-1967.

Food Item	Percent Volume	Percent Frequency of Occurrence
Animal	81.2	98.8
Mammals	67.1	95.0
Cottontail (*Sylvilagus floridanus*)	25.2	31.8
Prairie Vole (*Microtus ochrogaster*)	15.2	20.6
Deer Mice (*Peromyscus* spp.)	6.4	15.3
Raccoon (*Procyon lotor*)	5.5	10.0
Domestic Pig (*Sus scrofa*)	2.6	2.4
House Mouse (*Mus musculus*)	2.5	4.7
Fox Squirrel (*Sciurus niger*)	2.3	2.4
Opossum (*Didelphis marsupialis*)	1.7	4.1
Red Fox (*Vulpes fulva*)	1.0	28.2
Eastern Mole (*Scalopus aquaticus*)	0.9	0.6
Pine Vole (*Pitymys pinetorum*)	0.8	2.9
Undetermined Mammal	0.7	8.2
Short-tailed Shrew (*Blarina brevicauda*)	0.7	4.7
Woodchuck (*Marmota monax*)	0.6	2.9
Least Shrew (*Cryptotis parva*)	0.2	2.4
Eastern Chipmunk (*Tamias striatus*)	0.2	1.2
Bog Lemming (*Synaptomys cooperi*)	0.2	0.6
Striped Skunk (*Mephitis mephitis*)	0.1	1.8
White-tailed Deer (*Odocoileus virginianus*)	0.1	1.8
Domestic Dog (*Canis familiaris*)	0.1	1.2
Undetermined Rodent	T	2.4
Beaver (*Castor canadensis*)	T	0.6
Cow (*Bos taurus*)	T	0.6
Undetermined Shrew (Soricidae)	T	0.6
Undetermined Canidae	T	0.6
Birds	10.3	25.3
Domestic Chicken (*Gallus gallus*)	8.9	2.4
Meadowlark (*Sturnella magna*)	0.8	1.2
Undetermined Bird	0.3	14.7
Towhee (*Pipilo erythrophthalmus*)	0.1	1.8
Slate-colored Junco (*Junco hyemalis*)	0.1	1.2
Cardinal (*Richmondena cardinalis*)	T	3.5
Undetermined Goose (Anserinae)	T	0.6
Grackle (*Quiscalus quiscula*)	T	0.6
Guinea Hen (*Numida meleagris*)	T	0.6
Flicker (*Colaptes auratus*)	T	0.6
Reptiles	0.3	2.4
Undetermined Snake	0.2	0.6
Prairie Kingsnake (*Lampropeltis calligaster*)	0.1	0.6
Fence Lizard (*Sceloporus undulatus*)	T	0.6
Skink (*Eumeces* sp.)	T	0.6
Invertebrates	2.9	31.8
Short-horned Grasshoppers (Acrididae)	1.0	11.8
Caterpillars (Lepidoptera)	0.9	2.4
Long-horned Grasshoppers (Tettigoniidae)	0.8	4.1
Scarab Beetles (Scarabaeidae)	0.1	9.4

TABLE 1.—(Cont.)

Food Item	Percent Volume	Percent Frequency of Occurrence
Crickets (Gryllidae)	0.1	4.1
Flesh Flies (Sarcophagidae)	T	7.6
Undetermined Grasshoppers (Orthoptera)	T	4.7
Undetermined Beetles (Coleoptera)	T	2.9
Ants (Formicidae)	T	2.4
Undetermined Insects	T	1.8
Ground Beetles (Carabidae)	T	1.8
Ticks (Ixodidae)	T	1.2
Nocturid Moths (Nocturidae)	T	1.2
Undetermined Diptera	T	0.6
Spiders (Arachnida)	T	0.6
Centipedes (Chilopoda)	T	0.6
Leaf-footed Bugs (Coreidae)	T	0.6
Leafhoppers (Cicadellidae)	T	0.6
Marsh Flies (Sciomyzidae)	T	0.6
Carrion Beetles (Silphidae)	T	0.6
Undetermined Animal Materials	0.6	4.7
Plants	18.6	97.1
Persimmon (*Diospyros virginiana*)	10.2	15.9
Apple (*Malus* sp.)	3.1	5.9
Leaf-Stem-Bark Fragments	2.3	80.0
Grass (Gramineae)	1.6	86.5
Plum (*Prunus* sp.)	1.0	0.6
Pokeweed (*Phytolacca americana*)	0.2	4.1
Undetermined Plant	T	5.3
Clover (*Trifolium* spp.)	T	3.5
Lespedeza (*Lespedeza* spp.)	T	3.5
Undetermined Rose (Rosaceae)	T	2.9
Elm (*Ulmus* spp.)	T	2.9
Tick-clover (*Desmodium* spp.)	T	2.4
Moss (Polytrichaceae)	T	1.8
Corn (*Zea mays*)	T	1.8
Brambles (*Rubus* spp.)	T	1.2
Honey Locust (*Gleditsia triacanthos*)	T	1.2
Ragweed (*Ambrosia* spp.)	T	1.2
Broomweed (*Gutierrezia* sp.)	T	0.6
Cherries (*Prunus serotina*)	T	0.6
Moss (Dicranaceae)	T	0.6
Spanish Needle (*Bidens bipinnata*)	T	0.6
Field Bindweed (*Convolvulus arvensis*)	T	0.6
Mullein (*Verbascum thapsus*)	T	0.6
Smartweed (*Polygonum* sp.)	T	0.6
Partridge-pea (*Cassia fasciculata*)	T	0.6
Moss (Hypnaceae)	T	0.6
Carrot (*Daucus carota*)	T	0.6
Smooth Sumac (*Rhus glabra*)	T	0.6
Grape (*Vitis* sp.)	T	0.6
White Avens (*Geum canadense*)	T	0.6
Miscellaneous Materials	0.2	15.9
Undetermined Material	0.2	8.2
Stones	T	5.9
Lead Shot	T	1.8
Aluminum Foil	T	1.2

their investigations of red fox food habits but showed this food, for the most part, as an incidental item. Foxes ordinarily do not kill prey larger than woodchucks or chickens, but juvenile raccoons may be vulnerable (Errington, 1935). It was difficult to determine from stomach analysis whether raccoons were killed by foxes or were available as carrion. In 2 of 17 occurrences of raccoons, certain associated materials (flesh fly larvae or lead shot) suggested carrion.

The domestic pig, which appeared in 2.4 per cent of the foxes examined and contributed 2.6 per cent of the total volume, was suspected as being taken as carrion; flesh fly larvae were found in association with one occurrence. Korschgen (1957) reported pigs yielding a volume of 3.9 per cent and occurring in 5.2 per cent of his examinations. The disposal of dead pigs in fields is a common practice of farmers, and such procedures provide an easy source of food.

Mammalian foods of lesser importance which contributed 1.0 per cent or more of the total volume included the house mouse, fox squirrel, opossum, and red fox (Table 1). Remains of fox squirrels were detected in four foxes; two of these occurrences coincided with the squirrel hunting season in southern Illinois and might partially account for their presence in the diet of the red fox. The high occurrence (28.2 per cent) and low volumetric percentage (1.0) of red fox materials in the foxes examined may be largely attributed to accidental ingestion rather than to cannibalism. Mammals yielding minor quantities (Table 1) of food (less than 1.0 per cent by volume), although insignificant quantitatively, are important in that they demonstrate acceptance of a variety of foods by the red fox. Fourteen occurrences of undetermined mammalian remains were recorded; these contributed 0.7 per cent of the total volume.

Avian remains comprised 10.3 per cent by volume and 25.3 per cent by frequency of occurrence. Identification of birds was difficult because frequently little remained except a few feathers; hence, most identifications were "probable". In 25 instances birds could only be designated as undetermined avian material.

Volumetrically the domestic chicken was the most prominent bird in this study (Table 1). Scott and Klimstra (1955) reported that in Iowa this item proved to be one of the most frequent specific foods in the diet of the red fox. Two other large birds, a goose and a guinea hen, were also identified. Small birds such as the cardinal, meadowlark, towhee, etc. were recorded but added little quantitatively to the diet of the red fox (Table 1).

Although southern Illinois is rich in reptilian fauna, this was not reflected in the food habits of the red fox. Reptilian remains were detected in only four stomachs (Table 1); these included a fence lizard, skink, prairie kingsnake, and an unidentified snake. Scott (1943) recorded 5 reptiles in 923 red fox scats from trails. Korschgen (1957) found that cold-blooded vertebrates (fish and reptiles) occurred in 8 of 1006 red foxes; Scott and Klimstra (1955) reported 11 cold-blooded ver-

tebrates in 758 red fox scats from trails.

Invertebrates are common foods for the red fox but do not constitute a major food on a volumetric basis (Table 1). The principal invertebrates were insects; of these, only a few were prominent. Orthopterans (grasshoppers and crickets) were probably taken in greater relative amounts than any other insect (Table 1). Three families of beetles were identified. The prominent coleopteran family, the Scarabaeidae, had a frequency of occurrence of 9.4 per cent; most scarabs were *Phyllophaga*. Caterpillars comprised 0.9 per cent by volume and 2.4 per cent by frequency of occurrence; one stomach examined was gorged with this food.

Other invertebrates (Table 1) probably represented items picked up indirectly by the red fox. One of these items may have importance as an indicator of the nature of fox foods. Larvae of Sarcophagids, which may breed and give birth to young larvae in carrion (Borror and DeLong, 1964), were detected in 12 stomachs; in 8 there were indications that these larvae were associated with carrion.

Certain materials, such as bits of meat, bone fragments, and other associated items, could not be positively identified. Such items, designated as undetermined animal material, occurred in 4.7 per cent of the animals examined and composed 0.6 per cent of the volume.

Plant Foods

Plant materials were recorded in nearly all foxes examined but amounted to only 18.6 per cent of the total volume (Table 1). Grass or leaf, stem, and bark fragments, although frequently detected, usually were found in small quantities. Probably some of these items were accidentally acquired while the fox was engaged in normal food gathering activities or while the animal was in distress (trapped or wounded); Hamilton (1935) reported various grasses in the stomachs of foxes that had been shot. In a few instances the amount of grass suggested that a specific intent was shown by the fox to procure this material; Hamilton (1935) found that winter wheat was often consumed by foxes.

More than one-half of the total volume of plant food was persimmon which was recorded in 15.9 per cent of the stomachs and contributed 10.2 per cent of the volume. Gier and Gale (1946) found persimmon in similar proportions in Ohio red foxes. Apples, reported utilized by the red fox (Hamilton, 1935), were found to be a notable item in this study (Table 1). Apple orchards are abundant in southern Illinois and constitute a major agricultural land use. Other fruits, detected in lesser amounts, included cherry, plum, pokeweed, corn, bramble, and grape. Remaining plant items represented accidental ingestions.

Summary

Stomachs from 183 red foxes taken in Union County, Illinois, 1956-1967, were examined; 13 were unproductive of data. Animal foods were found in 98.8 per cent of the stomachs and constituted 81.2 per cent of the dietary volume. Plant materials, although frequently recorded, yielded only 18.6 per cent

of the total volume. Fifty-nine animal, 30 plant, and 4 miscellaneous items were identified; by volume only 11 animal and 5 plant foods represented 1 per cent or more of the diet. The most important foods by per cent volume were cottontail (25.2), prairie vole (15.2), persimmon (10.2), deer mice (6.4), and raccoon (5.5). The leading items by per cent frequency of occurrence were grass (86.5), leaf, stem, and bark fragments (80.0), cottontail (31.8), red fox (28.2), and prairie vole (20.6).

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SOME FACTORS RELATED TO WOOD SPECIFIC GRAVITY OF SHORTLEAF PINE IN SOUTHERN ILLINOIS

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ABSTRACT.—Latewood percentage accounted for thirty-six percent of the variation in wood specific gravity of plantation-grown shortleaf pine (*Pinus echinata* Mill.) in southern Illinois. All other variables measured in the study only accounted for an additional five percent. Soil moisture appeared to be the factor most closely related to specific gravity.

Shortleaf pine (*Pinus echinata* Mill.) occurs naturally in the extreme southwestern part of Illinois in a few scattered stands, but it has been extensively planted throughout the southern one-third of the state using seedlings of unknown seed source. Specific gravity of wood from these naturally occurring shortleaf pines in Illinois was much lower than for shortleaf in the State of Mississippi (Gilmore, 1963). However, it was concluded that specific gravity of wood can be affected by variation in latitude only to the extent that latitude reflects differences in rainfall, soil conditions, growing season, geographic race, or some other factor or combination of them that is directly related to tree growth and wood density. Effect of geographic race on specific gravity of wood was discounted in shortleaf pine plantations in Illinois (Gilmore, 1963) because of the unlikely probability of one or even a similar geographic race occurring throughout the Illinois plantations established from seed largely of unknown origin. He states that "the variation found in specific gravity of shortleaf pine in the two states (Illinois and Mississippi) must be attributed to either physiographic or climatic factors or both."

Gilmore *et al.* (1966) also reported that forty-nine percent of the variation in wood specific gravity of loblolly pine growing in southern Illinois was accounted for by percent of latewood and to environmental factors. The effects of environment and other measured factors upon the wood specific gravity of shortleaf pine growing in the general vicinity of the loblolly pine study are discussed in this paper.

METHODS

Sixty-one 1/10-acre plots were sampled in 13- to 28-year-old shortleaf pine plantations in 21 counties of southern Illinois contained within a north-south range of 100 miles. An extensive examination of topography, drainage, position on slope, spacing, and density of canopy was made before a plot was tentatively located in a plantation. Soil wells were dug at each corner of the tentative plot to determine soil uniformity. If all of the above conditions were reasonably uniform, measurements were made of the depth to an impervious soil layer and depth that

tree roots penetrated the soil (as judged by presence of roots in soil evacuated from soil wells). A composite sample of the top six inches of soil was taken at ten locations across the diagonals of the plot. Percentages of sand, silt, and clay of this top layer were determined by the hydrometer method.

On each plot the number of trees, heights of five dominant trees, and diameter at breast height (dbh) were measured. Cores were extracted from the five dominant trees at breast height (4.5 feet) with a 0.173-inch diameter increment borer.

Total age of each tree was estimated from ring counts on the core, plus three years. The amount of latewood in the breast-height cores was determined with a dendrochronograph. Volume of the green cores was determined by the method of Gilmore *et al.* (1961), and specific gravity was computed on the basis of oven-dry weight and green volume. Site index (height of dominant trees at 25 years) was obtained for each plot from local site index curves (Gilmore and Metcalf, 1961).

The air-line distance from each plot to one of thirty weather stations used in the study area was measured. The average monthly rainfall for June, July, August, and September was calculated from long-time precipitation records (Page, 1949). Monthly rainfall for each plot was recorded as the rainfall measured at the nearest weather station. Latitude was indicated for each plot as miles north of an east-west base line located near Paducah, Kentucky.

The data were analyzed by simple and multiple regression analyses. The variables used in the study are listed in Table 1.

TABLE 1.—Correlation Coefficients between Site Index, Percent Latewood, Specific Gravity, and Latitude for Shortleaf Pine Plantations and Soil and Climatic Features

Variable	Mean	Site Index	Latewood Percentage	Specific Gravity	Miles North of Kentucky
		Correlation Coefficients[1]			
Site index	38.9	.....	.33	.39	—.59
Miles north of Kentucky	41.0	—.59	—.37	—.39	.....
Depth of root penetration	15.0	.29	.25	.25	—.37
Depth to impervious layer	24.0	.21	.10	.20	—.14
Percent silt plus clay of topsoil	90.6	—.18	.02	—.01	—.14
June rainfall	4.1	.50	.17	.10	—.33
July rainfall	3.1	.26	.10	.12	—.34
August rainfall	3.7	.05	.02	—.04	—.25
September rainfall	3.5	.26	.17	.08	—.13
No. trees per acre	901.0	—.16	—.18	—.12	.08
Total height	33.8	.80	.36	.30	—.38
Age	20.8	.03	.14	.04	.15
Latewood percentage	19.7	.33	.....	.60	—.37
dbh	7.0	.36	.23	.15	—.15
Percent slope	5.5	.37	.09	.20	—.15
Core specific gravity	0.433	.39	.60	.....	—.39

[1] Significant at 5 percent level: .25; signficant at 1 percent level: .32.

Results and Discussion

Percentages of latewood explained more of the variation in wood specific gravity than any of the other variables tested (Table 1). But the amount of latewood produced by a tree depends upon a number of genetic and environmental factors. Those variables correlated with percentage of latewood in this study were (1) miles north of Kentucky, (2) site index, and (3) depth that tree roots penetrated the soil profile. All of these variables are either directly or indirectly related to soil moisture available for tree growth. For example, as the distance from the base line in Kentucky increases, the trees are shorter, usable soil depth decreases, and rainfall during the middle of the growing season is less.

Site index is a reflection of all the environmental factors affecting tree growth such as physiographic and climatic factors. In southern Illinois there are three distinct physiographic divisions (Leighton *et al.*, 1948), and each division has a pattern of soil development which reflects the moisture and nutrients available for tree growth. Climate affects tree growth mainly through rainfall and temperature variation within a region. Rainfall during the growing season averages 14 inches in the northern part and 16 inches in the southern part of the study area. Temperatures during the growing season vary widely in the study area, but high temperatures coupled with low rainfall usually result in a drought during July. Therefore, difference in moisture available for tree growth must be a reflection of the soil and also of current precipitation.

As roots penetrate the soil to a greater depth and occupy more of the soil profile, more moisture and nutrients should become available to the tree, enabling it to lay down more cells for wood production (Gilmore *et al.*, 1968). Added increment is in both height and diameter, with diameter growth being dense latewood cells (Gilmore *et al.*, 1966).

The relationship between specific gravity and the most potent variables as computed in the multiple-linear regression are shown in Table 2. Latewood percentage, the variable most closely related to specific gravity, explained thirty-six percent of the variation in wood specific gravity. All other variables statistically related to specific gravity only accounted for an additional five percent of the variation. This is eight percent lower than that found for loblolly pine in a similar study in southern Illinois (Gilmore *et al.*, 1966).

This study substantiates earlier findings of the effects that various

Table 2. Correlation Coefficients between Specific Gravity and Most Potent Variables.

Variables[1]	Correlation Coefficients[2]
1	.60
1, 2	.62
1, 2, 3	.63
1, 2, 3, 4	.64

[1] Variables: 1, latewood percentage; 2, miles north of Kentucky; 3, depth to impervious layer; 4, percent silt plus clay of topsoil.

[2] Correlations for variables 1, 2, and 3 significant at 1 percent level; for variable 4, at 5 percent level.

factors have on the wood specific gravity of loblolly pine in southern Illinois and on conifers in different sections of the United States. About one-half of the variation in wood specific gravity is unaccounted for in these reported studies, which suggest that either the methods used in the studies were not adequate or else genetics plays a more important role in determining wood specific gravity than has been previously reported.

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CIRCULATING IODOTYROSINES AND IODOTHYRONINES IN AMPHIBIANS

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ABSTRACTS—Circulating thyroid hormone patterns as determined by thin layer chromatographic analysis of butanol extracts of whole blood of amphibians showed that Necturus maculosus differed from the other urodeles in not having monoiodotyrosine as a major fraction. Thyroxine was detected in late tadpole and adult anurans. Free iodide was visualized in both anurans and urodeles except in Amphiuma means.

A recent study, undertaken to determine the differences between pre and postmetamorphic Mexican axolotls (*Ambystoma mexicanum*) showed that all or most of the circulating thyroid hormone was in the form of monoiodotyrosine (T_1) (Prahlad, 1968). Thyroidectomy or hypophysectomy abolished the presence of monoiodotyrosine in the blood indicating that it was formed in the thyroid gland under the influence of pituitary hormones. Recently (unpublished observations) it has been noticed that even a single injection of a large amount (4000 μg) of monoiodotyrosine to the premetamorphic Mexican axolotl does not induce metamorphosis. Thus, the role played by T_1 in body metabolism remains enigmatic not only in the Mexican axolotl but also in mammals (Rhodes, 1968). As there was very little information on the circulating thyroid hormones (Etkin, 1968, Rhodes, 1968, Thornburn, 1967) in various amphibians which differ in their metamorphic Status, a preliminary investigation was undertaken to determine the pattern of these circulating hormones.

METHODS AND MATERIALS

Several examples of urodeles and anurans were investigated (Table 1). These were obtained from commercial sources. However *Ambystoma mexicanum* used in this study was raised in our laboratory. It should be emphasized that some of these animals metamorphose spontaneously. All of the animals were anaesthetized in MS-222 prior to bleeding. In most cases blood was obtained by exposing the heart after opening the pericardium and cutting the sinus venosus. The blood was then drained into a vial. In some animals a 27 guage needle was thrust into the truncus and a quantity of blood was withdrawn into a syringe. In all cases a minimum of one cc of blood was obtained. These samples were analyzed by thin layer chromatography (TLC) according to previously described methods (Milstein and Thomas, 1966, Prahlad, 1968).

RESULTS

The technique used in the present investigation is capable of detecting the following fractions of iodinated

tyrosines and thyronines, from the point of origin to the solvent front: (1) Diiodotyrosine (at the point of origin (0)). (2) Monoiodotyrosine (T_1). (3) Free iodide (I). (4) Thyroxine (T_4). (5) Diiodothyronine (T_2) or triiodothyronine (T_3). (6) An unidentified fraction moving close to the solvent front. According to the investigations of Milstein and Thomas (1966), the TLC method is sensitive to approximately 0.1 μg of DIT, T_1, T_3 and T_4. The results of the current studies are shown in Figure 1. It is seen that the predominant fraction in Amphiuma and Ambystoma is T_1. This compound is detectable quite easily in late tadpole stages. All of the animals except Amphiuma show varying concentrations of I. T_4 is clearly visible in late tadpole, adult Rana pipiens and Xenopus laevis. T_2 is seen only in late tadpole. The absence of T_2 in the early tadpole

Thus, it is seen from the above observations that three urodeles, *A. mexicanum*, *A. tigrinum* and *Amphiuma means*, show similar patterns is enigmatic. No attempt was made to identify the fractions moving with the solvent front.

even though the three differ with respect to their life history and response to thyroid hormones. *Amphiuma means* is incapable of metamorphosis either natural or induced. *A. mexicanum* does not metamorphose spontaneously but is capable of responding to exogenous thyroid hormones (T_4 or T_3 or T_2). Even though *A. tigrinum* is capable of spontaneous metamorphosis no T_2 or T_3 or T_4 was detected within the limits of sensitivity of the technique used. *Necturus* maculosus, which is supposed to be permanently larval like *Amphiuma*, resembles the early bullfrog tadpole (an anuran) in its pattern of circulating thyroid hormones. It may be pertinent to point out that the postmetamorphic forms of both *A. tigrinum* and *mexicanum* show sloughing of skin frequently.

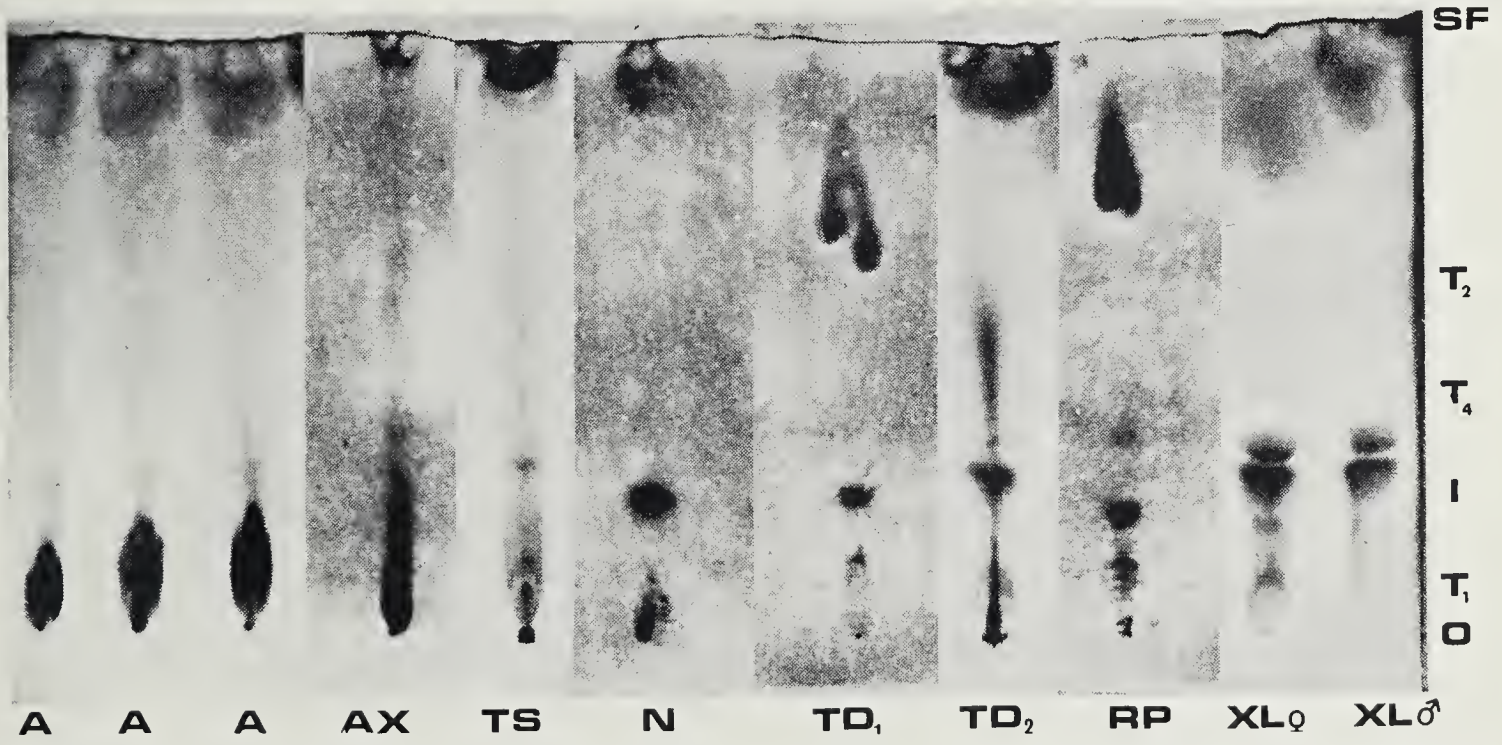

FIGURE 1. Thin layer chromatogram of butanol extracts of blood of Amphibians. From left to right on bottom: A-Amphiuma means. AX-Ambystoma mexicanum. TS-Ambystoma tigrinum. N-Necturus TD_1-young (no hind limbs but with limb buds) bullfrog tadpole. TD_2-older (small hind limb) bullfrog tadpole. RP-Rana pipiens. XL-Xenopus laevis. See the text for the rest of the abbreviations.

TABLE 1.—Amphibians used in the Present Investigation

Group	Genus and Species	Blood Obtained from Larvae or Adults	Metamorphic Status	Response to T_3 or T_4
Urodele	Amphiuma means (2)[1]	Larva	Permanently larval[2]	No metamorphosis
	Necturus maculosus (4)	Larva	" "	No metamorphosis
	Ambystoma mexicanum (6)	Larva	Permanently larval[2]	Metamorphoses
	Ambystoma tigrinum (3)	Adult	Temporarily larval[2] Metamorphoses Spontaneously	Metamorphoses
Anuran	Rana catesbeiana (6)	Tadpole	Temporarily larval Metamorphoses Spontaneously	Metamorphoses
	Rana pipiens (4)	Adult	....	....
	Xenopus laevis (4) ♀ and ♂	Adult	....	....

[1] Numbers in Parenthesis indicate the number of animals.
[2] Dent (1968).

Although this response has been clearly shown to be under the influence of thyroxine in *A. mexicanum* (Prahlad 1968) no T_4 was detected in the blood. Any explanation as to the significance of the present observations would only be speculative. Further investigations may clarify these enigmatic similarities and differences.

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CONCENTRATIONS AND DISTRIBUTIONS OF p,p′-DDE, DIELDRIN, AND HEPTACHLOR EPOXIDE IN PHEASANTS IN EAST-CENTRAL ILLINOIS

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Abstract.—Selected organs and tissues from 147 pheasants (*Phasianus colchicus*), collected in east-central Illinois during 1968, were analyzed by gas chromatography for p,p′-DDE, dieldrin, and heptachlor epoxide. p,p′-DDE was detected in 97 percent of the birds, dieldrin in 69 percent, and heptachlor epoxide in 75 percent. Mean concentrations of p,p′-DDE were greatest in livers (0.28±0.04 ppm); those of dieldrin and of heptachlor epoxide were greatest in subcutaneous fat (0.42±0.10 and 0.24±0.06 ppm, respectively). The highest individual concentrations were 3.26 ppm for p,p′-DDE, 5.76 ppm for dieldrin, and 4.76 ppm for heptachlor epoxide. Regressions indicated the entire body became contaminated by the respective toxicants when concentrations of p,p′-DDE in liver, or dieldrin or heptachlor epoxide in subcutaneous fat were greater than 6 ppm. Concentrations were greater during the summer months than at other times of the year, but sex- and age-associated differences were not demonstrated.

The chlorinated hydrocarbon insecticides have been in common use since the mid-1940's, when DDT was first used extensively. Since that time, millions of pounds of these toxicants have been applied to the earth's soils, waters, and air. Because of their stability, the chlorinated hydrocarbons, or their metabolites, often remain in the environment for several years, eventually finding their way into many species of plants and animals. It is this characteristic that makes the chlorinated hydrocarbon insecticides potentially dangerous to numerous organisms other than the target species.

The purpose of this study was to determine the presence, concentrations, and distributions of p,p′-DDE (a metabolite of DDT), dieldrin (a metabolite of aldrin and also a commercial insecticide), and heptachlor epoxide (a metabolite of heptachlor) in the bodies of pheasants in east-central Illinois, taking into consideration sex, age, and activity of the birds through the annual cycle. East-central Illinois supports the highest pheasant populations in the state (Labisky 1969:7) and also represents some of Illinois' most intensively cultivated farmland. Corn (*Zea mays*) and soybeans (*Glycine Max*) are the principal crops.

DDT, compared with other insecticides, was used extensively in Illinois agriculture — to control the corn borer (*Pyrausta nubilalis*) — from the late 1940's to the mid-1950's. Since the late 1950's, little DDT has been used for agricultural purposes in Illinois. Aldrin and, to a lesser extent, heptachlor were the most-used insecticides — for the control of a host of soil insects — in more recent years; these two chemicals were applied at rates of 1 to 1.5 pounds of technical material per acre. However, the use of both aldrin and heptachlor in Illinois de-

creased 25 percent from 1966 to 1968. Dieldrin was used sporadically from the mid-1950's to about 1964. (Information from H. B. Petty, Illinois Natural History Survey and University of Illinois College of Agriculture, Urbana.)

Methods

The pheasants used for this study were collected in Ford, Livingston, and Champaign counties during various periods in the annual cycle, in 1968 (Table 1). The birds were collected by nightlighting (Labisky 1968*a*) during the winter, prebreeding, and fall periods; by salvaging hens killed or mangled by hay mowers during the incubating period; and by shooting birds with an air-powered rifle during all other periods. In addition, 20 of the birds collected during the winter and prebreeding periods were taken with a shotgun, and 6 birds, representing four periods, were found dead along roads. The pheasants were aged as juveniles or adults by bursal examination. Juvenile birds collected during the growth and fall periods were further aged, to the nearest week, according to advancement of molt of the primary feathers (Labisky 1968*b*, p. 465).

Most of the pheasants were killed during the first 2 hours after sunrise. The birds that were collected by nightlighting were held overnight in padded crates, then sacrificed. With few exceptions, all birds were placed in polyethylene bags and then stored under refrigeration, immediately after they were sacrificed.

After the pheasants had thoroughly cooled, they were dissected to obtain samples of the organs and tissues to be analyzed for the toxicants. Subcutaneous fat was taken from along the posteroventral surface of the sternum and around the neck; visceral fat was obtained from deposits on the gizzard and in omentums of the intestine. In most instances, the samples of fat weighed a minimum of 2 grams. Some of the pheasants, notably growing birds and molting hens, had quantities of fat insufficient to be sampled.

Samples of muscle were obtained from the *femoris* and from the *pectoralis thoracica,* designated as leg muscle and sternal muscle, respectively. The muscle samples usually weighed from 10 to 20 grams, though those from growing birds were necessarily smaller (2-8 grams).

Internal organs that were analyzed were the liver, brain, gizzard lining, gizzard muscle, heart, kidneys, lungs, pancreas, and, during the nesting season, ovary, oviduct, and testes. Details of the dissecting procedures have been described elsewhere (Anderson 1969: 981). The entire organ, or pair of organs, was saved for analysis.

The samples were weighed immediately after being removed from the birds and were then placed individually in polyethylene bags and stored in a freezer for 1 to 9 months before being analyzed.

All samples were extracted with a 50:50 mixture of acetonitrile and hexane, then put through a florisil column for cleanup. The analyses for p,p′-DDE, dieldrin, and heptachlor epoxide were performed with a Beckman model GC-4 gas chromatograph equipped with an electron capture detector. Columns were packed with 1 percent EPON

TABLE 1.—Data for 147 pheasants from which selected organs and tissues were excised and analpzed for p,p′-DDE, dieldrin, and heptachlor expoxide, 1968, east-central Illinois.

Hens				Cocks			
Period	Date	Number of Hens	Mean Age (months)	Period	Date	Number of Cocks	Mean Age (months)
Juveniles				Juveniles			
Winter	Feb. 13-21	9	*ca.* 8	Winter	Feb. 13-21	8	*ca.* 8
Adults				Adults			
Winter	Feb. 13-22	12	>20	Winter	Feb. 13-21	4	>20
Prebreeding	Apr. 3-9	8	>10	Prebreeding	Apr. 2-9	10	>10
Breeding (Laying)	Apr. 22-May 29	12	>11	Breeding	Apr. 22-May 29	9	>11
Incubating	June 8-24	12	>12				
Molting	July 16-Aug. 5	10	>13	Molting	July 11-Aug. 15	10	>13
Fall	Oct. 14-25	8	>16	Fall	Oct. 10-25	8	>16
Juveniles				Juveniles			
Growth	July 24-Aug. 5	5	1.6 ± 0.1	Growth	July 11-Aug. 4	7	1.6 ± 0.1
Fall	Oct. 15-26	7	4.4 ± 0.1	Fall	Oct. 14-26	8	4.4 ± 0.2

resin 1001 and 0.5 percent Viton A fluoroelastomer on a solid support of 100-120 mesh chromosorb W. The lower limit of detection was considered to be 0.01 ppm.

Results

The levels of p,p′-DDE, of dieldrin, and of heptachlor epoxide in the various organs and tissues are presented in mean concentrations, in highest individual concentrations, and in frequencies of occurrence in Table 2-4. Predictably, these three parameters tended to be directly related to each other — if one was relatively high or low, so were the others. Concentration in the individual organs and tissues were high variable, with coefficients of variation ranging from 119 to 641 percent for p,p′-DDE, from 147 to 694 percent for dieldrin, and from 185 to 390 percent for heptachlor epoxide.

Of the 147 pheasants examined, p,p′-DDE was detected in 97 percent, dieldrin in 69 percent, and heptachlor epoxide in 75 percent. Ninety-nine percent of the birds contained detectable levels of at least one of the toxicants, 88 percent contained at least two, and 54 percent contained all three.

The levels of p,p′-DDE were highest in livers, followed closely by those in subcutaneous fat and in visceral fat, and distantly by those in lungs and in ovaries (Table 2). Levels of dieldrin and heptachlor epoxide were highest in subcutaneous fat, followed by those in visceral fat; levels in ovaries were a distant third (Tables 3 and 4). The highest individual concentrations were 3.26 ppm for p,p′-DDE (in liver),

Table 2.—Levels of p.p′-DDE in selected organs and tissues of pheasants collected in east-central Illinois in 1968. The samples consisted of birds of both sexes and of all ages (see Table 1).

Organs and Tissues	Number of Birds	Concentrations (ppm)		Frequency of Occurrence (percent)
		Mean	Highest	
Fat, subcutaneous	106	0.26 ± 0.03	1.67	75
Fat, visceral	100	0.22 ± 0.04	2.17	66
Muscle, leg	145	<0.01	0.13	8
Muscle, sternal	147	0.01 ± 0.005	0.73	6
Liver	147	0.28 ± 0.04	3.26	84
Brain	145	0.01 ± 0.004	0.59	3
Gizzard lining	146	0.01 ± 0.003	0.33	1
Gizzard muscle	147	0.01 ± 0.001	0.12	14
Heart	146	0.01 ± 0.002	0.16	13
Kidneys	143	0.02 ± 0.005	0.42	19
Lungs	144	0.05 ± 0.01	0.48	37
Pancreas	142	0.01 ± 0.005	0.50	4
Ovary*	28	0.06 ± 0.02	0.36	25
Oviduct*	31	0.02 ± 0.009	0.25	23
Testes†	28	0.01 ± 0.004	0.10	18

* The ovary and oviduct were taken from hens collected during the prebreeding, breeding (laying), and incubating periods only.

† Testes were taken from cocks collected during the prebreeding, breeding, and molting periods only.

TABLE 3.—Levels of dieldrin in selected organs and tissues of pheasants collected in east-central Illinois in 1968. The samples consisted of birds of both sexes and of all ages (see Table 1).

Organs and Tissues	Number of Birds	Concentrations (ppm)		Frequency of Occurrence (percent)
		Mean	Highest	
Fat, subcutaneous	106	0.42 ± 0.10	5.76	62
Fat, visceral	100	0.40 ± 0.09	5.09	57
Muscle, leg	145	<0.01	0.09	16
Muscle, sternal	147	<0.01	0.12	14
Liver	147	0.01 ± 0.006	0.48	10
Brain	145	0.02 ± 0.005	0.53	14
Gizzard lining	146	0.03 ± 0.004	2.14	13
Gizzard muscle	147	0.01 ± 0.003	0.37	22
Heart	146	0.02 ± 0.005	0.68	22
Kidneys	143	0.02 ± 0.004	0.33	20
Lungs	144	0.02 ± 0.005	0.42	28
Pancreas	142	0.03 ± 0.007	0.46	12
Ovary*	28	0.14 ± 0.04	0.71	57
Oviduct*	31	0.04 ± 0.020	0.56	35
Testes†	28	0.01 ± 0.004	0.08	21

* The ovary and oviduct were taken from hens collected during the prebreeding, breeding (laying), and incubating periods only.

† Testes were taken from cocks collected during the prebreeding, breeding, and molting periods only.

TABLE 4.—Levels of heptachlor epoxide in selected organs and tissues of pheasants collected in east-central Illinois in 1968. The samples consisted of birds of both sexes and of all ages (see Table 1).

Organs and Tissues	Number of Birds	Concentrations (ppm)		Frequency of Occurrence (percent)
		Mean	Highest	
Fat, subcutaneous	106	0.24 ± 0.06	4.76	59
Fat, visceral	100	0.20 ± 0.06	4.23	59
Muscle, leg	145	<0.01	0.05	6
Muscle, sternal	147	<0.01	0.33	6
Liver	147	0.03 ± 0.009	1.27	43
Brain	145	<0.01	0.05	3
Gizzard lining	146	<0.01	0.25	1
Gizzard muscle	147	<0.01	0.08	10
Heart	146	<0.01	0.08	5
Kidneys	143	0.01 ± 0.003	0.37	14
Lungs	144	<0.01	0.09	7
Pancreas	142	<0.01	0.09	1
Ovary*	28	0.05 ± 0.02	0.32	36
Oviduct*	31	<0.01	0.04	19
Testes†	28	<0.01	0.02	7

* The ovary and oviduct were taken from hens collected during the prebreeding, breeding (laying), and incubating periods only.

† Testes were taken from cocks collected during the prebreeding, breeding, and molting periods only.

5.76 ppm for dieldrin (in subcutaneous fat), and 4.76 ppm for heptachlor epoxide (in subcutaneous fat), which occurred in adult hens collected during the incubating period.

Concentrations of p,p′-DDE in livers, and of dieldrin and of heptachlor epoxide in subcutaneous fat, were found to be directly related to the percentage of the selected organs and tissues that were contaminated by these toxicants. These relationships, which were significant at the 0.001 level of probability, are illustrated with dieldrin in Figure 1. The regression lines indicated that all of the organs and tissues analyzed might be expected to be contaminated by the respective toxicants if concentrations of p,p′-DDE in liver, or dieldrin or heptachlor epoxide in subcutaneous fat, were greater than 6 ppm.

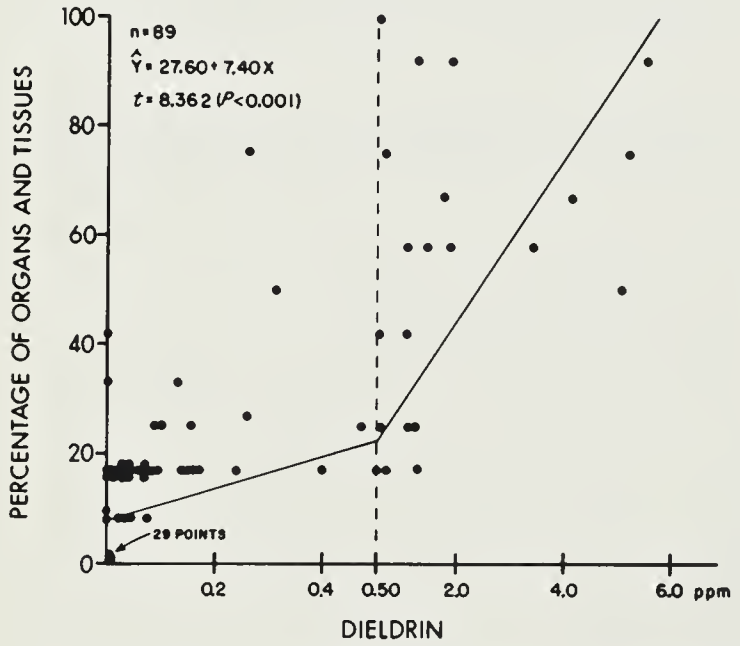

FIGURE 1. Relationship, as determined by linear regression, between concentrations of dieldrin in subcutaneous fat of pheasants and the percentage of selected organs and tissues that contained detectable levels (had concentrations of 0.01 ppm or greater) of this toxicant, east-central Illinois, 1968. The organs and tissues are: subcutaneous fat, visceral fat, leg muscle, sternal muscle, liver, brain, gizzard lining, gizzard muscle, heart, kidneys, lungs, and pancreas. Note that the scale on the horizontal axis changes by a factor of 10 at 0.50 ppm.

Mean concentrations of the three toxicants did not differ significantly among pheasants representing the different sex-age groups (Table 5). Failure of some of the differences, particularly the larger ones, to be significant is attributed to large variations that occurred in the data. Adult hens were perhaps carrying higher levels of dieldrin and heptachlor epoxide than juvenile hens (Table 5).

Seasonal changes in levels of p,p′-DDE, of dieldrin, and of heptachlor epoxide in the pheasants are presented graphically in Figures 2 and 3. In both sexes, the levels of the three toxicants began to increase during late April and May (breeding period) and, in hens, reached their highest levels during June (incubating period); cocks were not collected during June. With the possible exception of heptachlor epoxide, the levels decreased from July and early August (molting period) to October (fall period).

In 120 pheasant eggs, collected in east-central Illinois in 1966, the frequencies of occurrence of p,p′-DDE, dieldrin, and heptachlor epoxide were 99, 99, and 51 percent, respectively. Concentrations in the entire egg, excluding shell and membrane, averaged 0.15±0.02 ppm for p,p′-DDE and 0.30±0.08 ppm for dieldrin. The highest individual concentrations were 0.61 ppm for p,p′-DDE, 2.82 ppm for dieldrin, and 0.40 ppm for heptachlor epoxide. (Data from Greenberg and Edwards 1970.)

TABLE 5.—Mean concentrations (ppm) of p,p′-DDE, dieldrin, and heptachlor epoxide in pheasants of four sex-age groups, east-central Illinois, 1968. Sample sizes are in parentheses.

	Hens		Cocks		
	Juveniles	Adults	Juveniles	Adults	*F**
p,p′-DDE in livers					
Winter (Feb. 13-21)	0.05 ± 0.02(9)	0.28 ± 0.20(12)	0.11 ± 0.06(8)	0.07 ± 0.04(4)	0.54
Summer (July 11-Aug. 15)	0.63 ± 0.21(5)	0.40 ± 0.16(10)	0.64 ± 0.25(7)	0.38 ± 0.18(10)	1.56
Fall (Oct. 10-26)	0.21 ± 0.05(7)	0.20 ± 0.08(8)	0.15 ± 0.02(8)	0.14 ± 0.03(8)	0.49
Combined	0.24 ± 0.07(21)	0.30 ± 0.10(30)	0.28 ± 0.09(23)	0.26 ± 0.09(22)	0.13
Dieldrin in subcutaneous fat					
Winter	0.04 ± 0.03(8)	0.06 ± 0.05(12)	0.01 ± 0.005(8)	0.03 ± 0.025(4)	0.33
Fall	0.02 ± 0.020(4)	0.09 ± 0.04(8)	0.19 ± 0.07(2)	0.04 ± 0.02(4)	0.14
Combined	0.04 ± 0.02(12)	0.07 ± 0.03(20)	0.05 ± 0.03(10)	0.04 ± 0.01(8)	0.05
Heptachlor epoxide in subcutaneous fat					
Winter	0.01 ± 0.005(8)	0.11 ± 0.04(12)	0.03 ± 0.01(8)	0.01 ± 0.013(4)	2.88
Fall	0.01 ± 0.020(4)	0.52 ± 0.41(8)	0.07 ± 0.07(2)	0.02 ± 0.019(4)	0.58
Combined	0.01 ± 0.007(12)	0.29 ± 0.17(20)	0.04 ± 0.02(10)	0.02 ± 0.011(8)	1.21

* Analysis of variance; none of the differences among means were significant at the 0.05 level of probability.

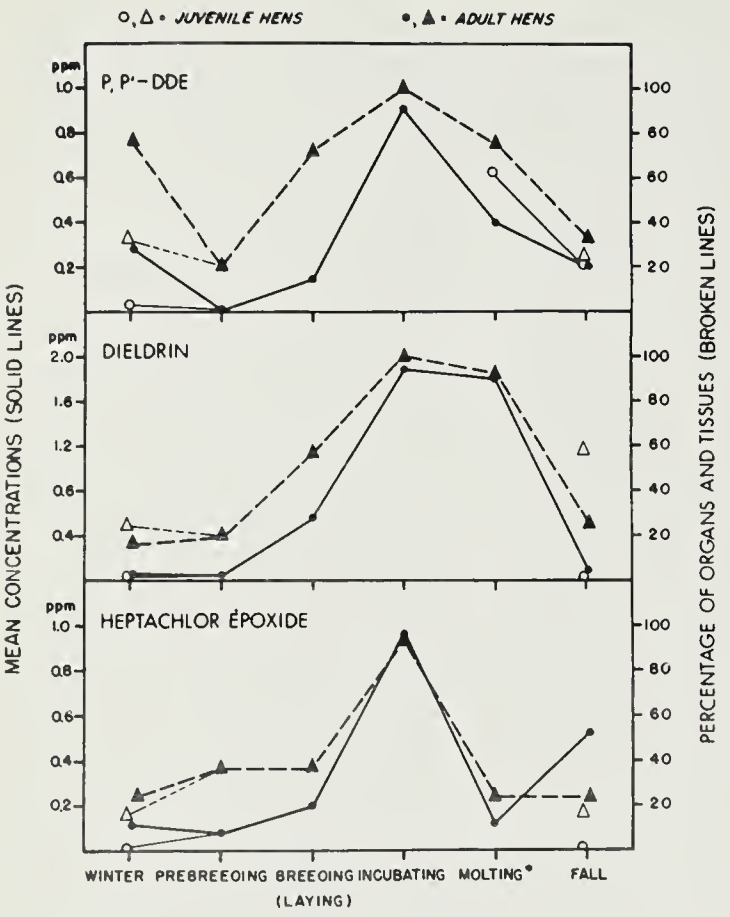

FIGURE 2. Seasonal changes in mean concentrations of p,p′-DDE in livers, of dieldrin in subcutaneous fat, and of heptachlor epoxide in subcutaneous fat, and in the percentage of selected organs and tissues that contained detectable levels (had mean concentrations of 0.01 ppm or greater) of these toxicants, hen pheasants, east-central Illinois, 1968.

*Growth period for juvenile hens.

DISCUSSION

Findings of this study indicate that all, or almost all, pheasants in east-central Illinois are contaminated with p,p′-DDE, dieldrin, or heptachlor epoxide, although the actual concentrations are low. It is noteworthy that 97 percent of the pheasants examined carried detectable concentrations of p,p′-DDE, considering the decline in the use of DDT in Illinois agriculture since the mid-1950's. Similar findings have been reported for pheasant eggs collected in east-central Illinois in 1966 (Greenberg and Edwards 1970). If pheasants are reliable indicators, these findings suggest that most of the agricultural environment in east-central Illinois was contaminated with DDT, aldrin, or heptachlor, or their metabolites, during the mid-1960's.

The failure to find other than low concentrations of p,p′-DDE, dieldrin, and heptachlor epoxide during this study (Tables 2-4) suggests that these chlorinated hydrocarbons do not pose a major threat to the pheasant population in east-central Illinois. The highest individual concentration, 5.76 ppm, was for dieldrin in subcutaneous fat. Only 3, 14, and 3 percent of the 145 brains analyzed contained detectable concentrations of p,p′-DDE, dieldrin, and heptachlor epoxide, respectively; the highest individual concentra-

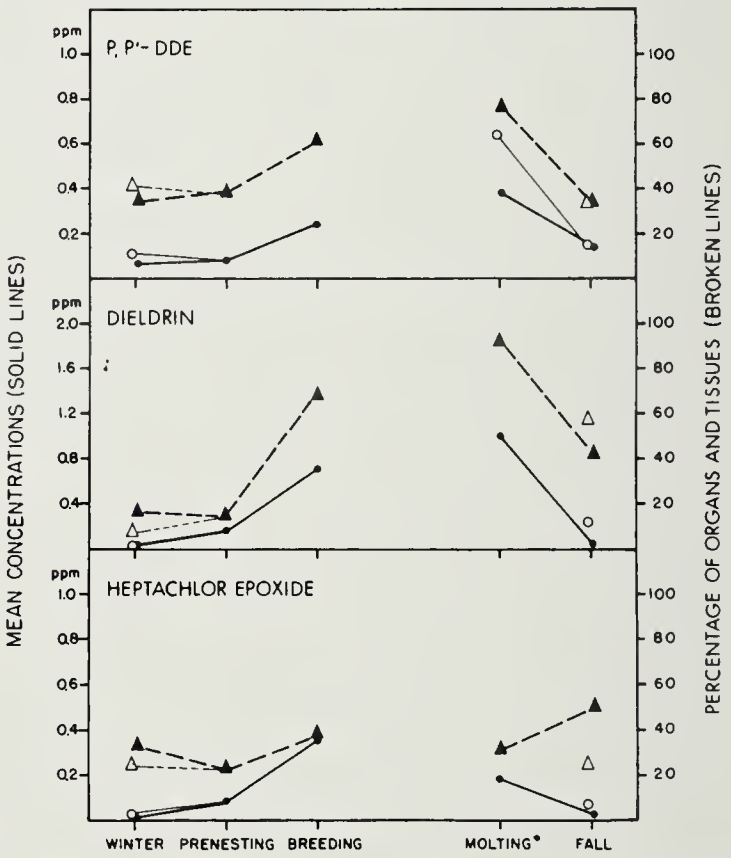

FIGURE 3. Seasonal changes in mean concentrations of p,p′-DDE in livers, of dieldrin in subcutaneous fat, and of heptachlor epoxide in subcutaneous fat, and in the percentage of selected organs and tissues that contained detectable levels (had mean concentrations of 0.01 ppm or greater) of these toxicants, cock pheasants, east-central Illinois, 1968.

*Growth period for juvenile cocks.

tions in brains were, respectively, 0.59, 0.53, and 0.05 ppm.

However, the foregoing findings do not preclude the possibility that chlorinated hydrocarbon insecticides might be impairing reproduction of pheasants in Illinois. Baxter et al. (1969: 101), after conducting dieldrin studies on penned pheasants, concluded that food consumption and egg production by a group of eight experimental hens were less than those of eight control hens. The experimental hens had not been exposed directly to dieldrin, but were hatched from a group of eggs, the yolks of which contained, according to analyses of eight eggs, 13.3 to 52.4 ppm of the toxicant (Atkins and Linder 1967: 747). The parent hens had been given 6 mg of dieldrin per week during the time these eggs were produced. A pooled sample of brains from three of the eight experimental hens contained 0.07 ppm of dieldrin (Baxter et al. 1969: 99). Of the 145 Illinois pheasants from which brains were analyzed, 15 (10 percent) contained concentrations of dieldrin that were 0.07 ppm or greater; six of these birds occurred in a sample of 12 hens collected during the incubating period. The findings by Baxter et al. need to be substantiated — or refuted — with additional research.

There is little doubt that chlorinated hydrocarbon insecticides are passed from adult hens to their offspring via the egg. p,p′-DDE, dieldrin, and heptachlor epoxide were detected in 25, 57, and 36 percent, respectively, of the ovaries analyzed (Tables 2-4). And, most of the pheasant eggs in a sample of 120 collected in east-central Illinois in 1966 contained these toxicants (Greenberg and Edwards 1970).

Although chlorinated hydrocarbons are known to concentrate in certain tissues, findings of the present study indicate that p,p′-DDE, dieldrin, and heptachlor epoxide can occur in many parts of the body (Tables 2-4). At concentrations of 6 ppm or greater of p,p′-DDE in liver or of dieldrin or heptachlor epoxide in subcutaneous fat, the respective toxicants can be expected to occur throughout the body (Fig. 1). Dieldrin appeared in brains of birds in which 50 to 100 percent of the organs and tissues analyzed were contaminated with this toxicant. It appears probable that the entire body becomes contaminated when only small amounts of p,p′-DDE, dieldrin, or heptachlor epoxide enter the birds. If sex and age affect the extent to which pheasants become contaminated with these chlorinated hydrocarbons, the effects were not demonstrated during this study (Table 5).

The increases in levels of p,p′-DDE, of dieldrin, and of heptachlor epoxide in pheasants, that began during late April and May and continued into June (Figs. 2 and 3), correspond to the time at which farmers normally treat their fields with insecticides. However, factors other than amounts of toxicant present in the environment must have contributed to the increase of p,p′-DDE in the pheasants because, as noted above, this chlorinated hydrocarbon has not been used appreciably in Illinois agriculture since the late 1950's. Perhaps greater consumption of animal material or shifts in physiological mechanisms contribut-

ed to the spring-summer increase of p,p′-DDE, as well as to those of dieldrin and heptachlor epoxide, in the pheasants.

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TEMPORAL VARIATION IN THE SPECIES DIVERSITY OF A WOODLAND CADDISFLY FAUNA FROM CENTRAL ILLINOIS

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ABSTRACT.—The species diversity as measured by H of the adult caddisfly fauna of the Nettie Hart Woodland Memorial near Mahomet, Illinois, was calculated for one night a week from May 26 to September 18, 1966. The calculated diversity values were much less variable than the population levels of the individual species as measured by the coefficient of variation. The coefficient of variation of the H values was .3201, but the range of the coefficients of the individual species was from .5876 to 1.7060. It is hypothesized that this indicates that some organization exists in the community such that a change in the population level of one species is not independent of the populations of the other species. Their was no significant correlation between commonness and variability in the ten commonest species.

An important question in the measurement of species diversity in natural communities is whether diversity measures reflect an inherent organization of the community or only a random assemblage of species. If the species diversity of a group of organisms is less variable than that of the populations of the component species, it is possible that a degree of organization is present, smoothing over differences caused by changes in the densities of individual species.

METHODS

A study was made of the adult caddisfly community in the Nettie Hart Woodland Memorial near Mahomet, Illinois. An ultraviolet, 15-watt, black-light trap was run every night for one year along the Sangamon River by Dr. Milton W. Sanderson of the Illinois Natural History Survey. The trap was located in the woods between the bank of the river and a small tributary stream. The catch from each night was preserved in 70 percent alcohol and stored. Catches from 17 nights, taken at approximately weekly intervals from May 26 to September 18, 1966, were sorted and all of the adult caddisflies of the families Hydropsychidae, Psycomiidae, Leptoceridae, and Rhyacophilidae were identified. The Hydropsychidae, Psycomiidae, Leptoceridae, and Rhyacophilidae are roughly of the same size grouping and make up about 95 percent of the caddisfly fauna at this location.

The diversity index used was H (information theoretical) and was calculated using the formula

$$H = \frac{c}{\overline{N}} \left(\log_{10} N! - \log_{10} n_i!\right)$$

and the tables given in Lloyd *et al.* (1968). H rather than H′ was used because the samples were not taken randomly (Pielou, 1966), and the sample had to be considered as a population unto itself. The parameter c in this case equals 2.302585

and is used for conversion of logarithms from the base 10 to the base e. The total number of individuals is represented by N, and the number of individuals per species by n_i. The calculated diversity for each of the 17 nights is given in Table 1. Diversity as measured by H is influenced by three factors: the number of species in the sample, the number of individuals, and a component measuring the shape of the distribution of individuals to species. This second component has been termed "evenness" by Pielou (1966).

TABLE 1.—Summarized data for each of the 17 night's catches from May 26 to September 18, 1966.

	Individuals	Species	Males	Females	H
May 26	114	5	53	61	.4576
June 3	196	8	116	80	1.0348
June 12	974	14	442	532	1.5535
June 17	157	12	75	82	1.6742
June 23	521	13	278	243	1.8702
June 30	668	14	323	345	1.7250
July 6	712	15	244	468	1.9601
July 14	1,305	8	333	972	1.1401
July 22	667	11	258	409	1.5311
July 26	801	15	321	480	1.6531
August 4	175	9	92	83	1.4828
August 12	264	10	102	162	1.6640
August 19	324	13	91	233	1.8487
August 25	772	10	413	359	1.4206
September 4	441	11	253	188	1.3254
September 8	326	11	232	94	1.1884
September 18	70	6	41	29	1.2304

RESULTS AND DISCUSSION

The hypothesis was that the temporal variability of H was the same as that of the species in the community. The percentage of each species in a single night's catch was computed and averaged over all 17 nights. It is not possible to make generalizations about the true abundance of each species because the number of caddisflies caught any night is dependent on weather. The standard deviation of each species' frequency was also computed. Using these two statistics, the coefficient of variation for the 10 commonest species was computed, an analysis suggested by Dr. Monte Lloyd of the University of Chicago. Similarly the mean and standard deviation of H for the period of 17 nights was calculated. The antilogarithms to the base e of the calculated H values were taken before calculating the coefficient of variation, because H is on the log scale and not directly comparable to the coefficients of variation of the species.

The coefficient of variation for the H measure is .3201 and falls well below the range of the component species (Table 2), indicating that the variation of diversity as measured by H is less than that of the component species.

TABLE 2.—Coefficients of variation and total number of individuals of the 10 commonest caddisfly species.

	Total Individuals	Coefficient of Variation
Cheumatopsyche analis	2,258	.7436
Hydropsyche orris	2,237	.6303
Potaymia flava	1,807	1.2560
Ocestis inconspicua	666	.5876
Leptocella candida	357	1.4211
Polycentropus cinereus	350	.9675
Hydropsyche betteni	272	1.1725
Athripsodes transversus	256	1.2541
Trianodes aba	65	1.7060
Nyctiophylax vestitus	53	1.1332

The data suggested that the populations of the commoner species in the community fluctuated less than the rarer species. A correlation coefficient (r) was calculated using the log total number of individuals of each of the 10 commonest species as the x variable and the coefficient of variation as the y variable. The calculated r was .3371 and is not significant. Prior to the beginning of the study, it was also hypothesized that there would be significant correlations between the population fluctuations of the three commonest species and the fluctuation of H. A regression analysis of the population levels of each of the three commonest species against H were calculated, but none of the three was significant.

The possible implication of this study is that organization, as measured by H, probably exists in natural communities, and the fluctuations of species populations are not entirely random with respect to other related members of the community. The possibility of the lower variation of H being a statistical artifact cannot, as yet, be ruled out.

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CANNABIS TOXICOMANIA

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ABSTRACT.—*Cannabis* toxicomania is an inordinate desire for, and use of, hashish. Known by many names, and used widely in various forms throughout the world, *Cannabis* is now used increasingly by young people in most western countries. While many studies of this drug have been reported, many questions about it need further research. Reasons for the use of *Cannabis* are offered, and the rationale of psychotherapy for addicts is given.

Toxicomania may be literally defined as an exceedingly strong attraction or desire for a toxin or poison. *Cannabis* is hashish or the dried pistillate parts of Indian hemp. It is often in the news by the name of marijuana, grass, pot, and other terms. Statistics on *Cannabis* toxicomania show a sharp upward curve at the present time. This is a phenomenon of social pathology.

Cannabis is a plant of the family *Urticaceae,* which grows on all continents, almost everywhere. Certain varieties, such as *Cannabis indica,* are richer in active principle than are others such as *Cannabis sativa. Cannabis* is a very resistant plant, is easily cultivated, and is grown in pots in New York City and on the lawns of the Tiergarten in Berlin as well as on the balconies of St. Louis Island in Paris, usually clandestinely by hashish addicts.

The drug is extracted from female plants. Sap or resin, which contains approximately forty percent of active principle, is absorbed from the digestive tract. Flowers or leaves, which contain approximately ten percent of active principle, are smoked. *Cannabis* is eaten, swallowed or smoked according to different likings in different countries.

In India it is drunk with water, alcohol, or opium tincture. In Iran *Cannabis* is eaten in cakes prepared with butter and rose oil. In the Middle East it is taken in a mixture with opium, nuxvomica, and datura, or as a jam. In Egypt a drink is made of *Cannabis,* sugar and aromatic vegetable substances. In Africa *Cannabis* is usually smoked. It is called "kif" in Morocco, and "takrouri" in Tunisia. In the western world the dry leaves are usually incorporated with small quantities of tobacco and are smoked like a cigarette.

The hallucinogenic effects of *Cannabis* have been known for centuries. In the past, writers have been attracted to *Cannabis,* either by need as was Charles Baudelaire (1821-1893), by experimental purpose as was Teophile Gautier (1811-1872), or to fight against organic suffering as did Guy de Maupassant (1850-1893). Samuel Taylor Coleridge (1772-1834) was also a drug user.

In 1845 a French doctor, Moreau de Tours, tried to use *Cannabis* to treat mental disease. He soon realized that far from having a salutary effect, this plant produced a mental disorder, temporary but intense.

At the beginning the use of *Cannabis* in Europe was limited to the Mediterranean countries, — European Turkey, Greece, Albania, Yugoslavia and Sicily. Then followed ethnic minorities such as the Armenians and Arabs in Paris, then certain social groups like the Bohemians, beatniks, hippies, and later the artists and musicians. Finally the use of the drug has involved all social classes, particularly students and graduates of secondary schools, though rarely teachers.

Today *Cannabis* toxicomania pervades all western countries. Quick and easy international traffic, tourism, and business from Asiatic and African countries, where the plant is cultivated and commercialized, allow wide dispersion. Nevertheless, the fact that dispersion occurs, in spite of international control and repression, implies great demand. And demand is certainly great. For example the annual reports of the United Nations Commission for Drugs inform us that in 1957 only 123,560 kg of *Cannabis* was seized, but in 1967 the amount seized was 1,389,005 kg.

What accounts for the attraction of *Cannabis*? What is the nature of the active principle?

Any substance that modifies sensations, perceptions, conscience, and self-perception is a drug. There are three classes of drugs:

a) Drugs that are habit-forming, create physical and psychical dependence and cause cerebral and other organic lesions, for example morphine, heroin, and alcohol.
b) Drugs that are not habit-forming but which cause physical and intellectual injury, for example L S D and amphetamine.
c) Substances which are neither habit-forming nor injurious, like tea.

Cannabis as yet cannot be classified in any of these categories. It has not been possible to ascertain the organic, physiological and intellectual alterations which may follow the use of this drug. Research has been insufficient so far, and absolute innocuity of *Cannabis* has not been established. Strong controversy exists on this subject, but the escalade from *Cannabis* to other drugs seems to be admitted.

The first studies of this plant were made by scholars who went to Egypt with Napoleon Bonaparte. Silvestre de Sacy and Rouyer brought samples of this plant back to Paris, and these were studied by Lamarck. In the second half of the last century Cahn obtained from *Cannabis* an alkaloid, cannabinol, in a pure state, and over a period of years determined its structure (Cahn, 1930-33). A second alkaloid, cannabidiol, was isolated by Todd and Adams, and its formula elucidated by Mechoulam and Shvo (1963).

It is a peculiarity to be pointed out that these alkaloids do not contain nitrogen. To produce the effects known by drug users cannabinol must be combined to four atoms of hydrogen, becoming tetrahydrocannabinol, which is responsible for the physiological effects of *Cannabis*. (Figure 1)

Professor Jean Delay of Paris classifies psychotropic drugs by their action. According to him *Cannabis* is not a psycholeptic drug that di

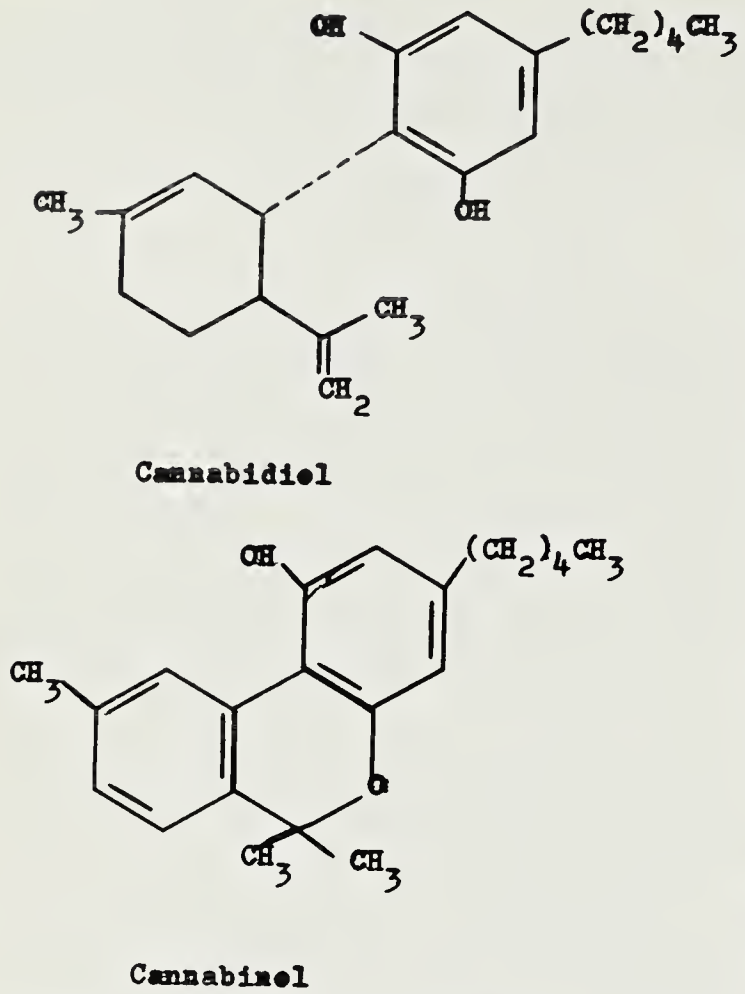

FIGURE. 1. Structural formulas for two alkaloids.

minishes mental activity, like barbiturics and other hynotics. It is not a psychoanaleptic drug which stimulates mental activity, like amphetamine. It is a psychodyslepic drug, which deviates and distorts mental activity.

The effects of *Cannabis* vary according to the dose absorbed, and they last four to six hours. After the smoking of a marijuana cigarette and a period of throat irritation with cough, a three-phase scheme of effects can be determined.

1) A phase of euphoria, hilarity, amplified imagination, liberation from inhibitions, and ease of social contact.
2) A phase of excitement, aggressiveness, agitation, violence sometimes even with audile and visual hallucinations, depersonalization, and fright.
3) A phase of clumsiness, dullness, and ecstasy similar to the "motionless rest" of Orientals.

The word "assassin" comes from the Arab word "hashishin" meaning hashish smoker, and it relates to a reputedly historic fact. In the year 483 of the Hegira, Caliph Hassan — called the "Old Man from the Mountain" — in order to strengthen his power created the order of hashishins. When he wanted to get rid of any enemy, he administered *Cannabis* to his confident servant, who did not hesitate to put a person to death after being given his mission during intoxication.

In western countries the practice of toxicomania is largely a social matter, in origin and in consequences. However, the motivation or preconditioning of individuals determines participation in this social group activity.

Youngsters of both sexes meet in clandestine clubs, as in ceremonials of religious sects. Their meetings are secret, in poor light, and sometimes with soft music. The atmosphere is friendly, and persons lie on the ground or floor, or on sofas, and they take off their shoes.

Motivations for such meetings are mixed and many. They include curiosity, attraction of the forbidden, apprehension of solitude, search for fellowship, the feeling of being understood by members of the group, and protest against a society which they feel deceives them. According to their own declarations, they try to deepen or widen the field of their own conscience, to reach a higher degree of perception, to surpass themselves, to improve, to see further and more intensively than they do in their every-day monoton-

ous life. *Cannabis,* which has been used in the Far East for centuries, permits those who take it—according to cunning propaganda — to reach oriental wisdom.

A lag between generations has always existed. But in the present world the acceleration of change has greatly increased an awareness of this lag. Youngsters who are apprehensive about their future and yet are anxious to take on responsibilities in society, are reluctant to accept a ''sick society''. They question morals, religions, politics and the nation, and they cannot make sure of their feelings toward any established group.

Nevertheless it should be noted that not all youngsters fall into toxicomania in spite of discouragement, in spite of the western conscience crisis, and notwithstanding the consumers' society which is made responsible for all our miseries today. Those who take drugs are the ones who retreat quickly when facing difficulties, who ''follow the crowd'' because they wish not to be different from their peers. This social phenomenon of contagion or imitation is involved in the current epidemic of *Cannabis* toxicomania.

What prophylaxis or prevention is available? Would educational campaigns, with information and moralization, or would coercion of drug users, restrain toxicomania and diminish its consequences? We wish it would, but we do not think it would. Some people recommend persecution and high penalties for all who, for money, are associated with the distribution of *Cannabis.*

As for the consequences of toxicomania certain observations indicate that the use of *Cannabis* leads to the use of drugs that create physiological dependence with organic need, for example heroin. Other observations show psychical dependence, even on *Cannabis.*

Dependence, in turn, leads into medico-legal aspects of the problem. The dependent individual spares no sacrifice to get the herb. Any and all means to acquire money to buy the drug are good. The user becomes a peddler. He employs attack, hold-up, theft, burglary, forgery of checks, and all sorts of frauds, though less frequently than other drug addicts.

Also, under the effect of the drug, *Cannabis* smokers, drinkers and eaters can commit blows and wounds during the phase of excitement, or aggression while in a paranoid state, and various escapades in their fright. The word ''assassin'' is not idly associated with hashish smoker.

What psychological type of persons become drug addicts? Generally addicts are persons who have not been educated to face life's difficulties. They correspond to adolescents and young adults who were spoiled in childhood, who were brought up in a dull and close atmosphere, or who were not wanted, were abandoned, or grew up in a broken home. They were badly trained to overcome obstacles or to endure misfortunes, poorly trained to avoid or cope with reverses, or to wait patiently when occasion demands. They dismiss their problems by trying to substitute an artificial paradise of drug for the paradise they lost in childhood.

Most drug takers lack self-reliance and confidence in their potentialities.

They have an inferiority complex. They are impatient, are tense with their suppressed aspirations, and are quickly deceived by life.

These anomalies occur also in neurotics and in candidates for suicide. As a matter of fact toxicomaniacs, neurotics, and candidates for suicide show similar psychological profiles to a certain point. This is the reason why the punishments applied to toxicomaniacs are out of date, we think. Often toxicomania and neurosis occur at the same time in an individual and are linked to ideas of suicide. Denial of reality with its difficulties, for the advantage of an imaginary world, is anyhow an attenuated form of suicide.

As well as for the neurotic and the suicidal, the best therapeutic results may be obtained for the toxicomaniac by direct psychotherapeutic action, — in its conscious and unconscious aspects. This action being both therapeutic and pedagogic, it will amplify the patient's sense of identity in his social group. It will restore his self-confidence, and facilitate his comprehension of genuine cultural values. It will prepare him for integration into the society which he had always criticized while not recognizing its obvious and unquestionable values. Of course this psychotherapeutic dialogue is conducted with the tact and the intuition of an experienced psychiatrist.

The torturing inferiority sense of the toxicomaniac originates in early childhood. It puts into operation a compensation by suppressing aspirations and making exaggerated demands of life. Sometimes there occurs an over-estimation of oneself. But the delusions of these dreamers are quickly lost, and they lead to despair, to deception, to dismissal of real life. The drug permits them to escape into an imaginary world. Their clandestine meetings give them an impression of social life. Their mechanism of projection makes society responsible for their miseries.

The therapist endeavors to detect the inferiority sense and its origin by way of the rational and irrational elements of the individual, in everyday events, and through day dreams and night dreams. The therapeutic effort is directed to turning the suppressed aspirations to more reasonable proportions, which may be satisfiable. It puts revolt and protest under the control of self-criticism and into the light of the individual's increasing consciousness. It enlarges his social sense and leads him to social integration.

While research on *Cannabis* continues and we await results in regard to harmful or innocuous effects, what attitude toward it should be adopted? Should it be hostile and prohibiting? Should it be acquiescent and accepting? It seems to the authors that an attitude of tacit tolerance would be most wise.

Acknowledgment

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ADDITIONS TO THE FLORA OF CLARK COUNTY, ILLINOIS, FROM THE ROCKY BRANCH NATURE PRESERVE

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ABSTRACT.—A floristic study was made of the Rocky Branch Nature Preserve during the growing seasons of 1967 and 1968. This 130 acre area, located on the Illinoian till just south of the Shelbyville Moraine, is highly variable ecologically. A total of 445 species were found, of which 120 were new records to Clark County, Illinois. Some of these species are extremely common but have been previously overlooked; others are extremely rare, having been reported sporadically or not at all from East-Central Illinois.

The Rocky Branch Nature Preserve is located six miles northwest of Marshall (Sect. 29 & 30, T12N, R12W), Clark County, Illinois. It is situatel on the till of the Illinoian glacier about 5 miles south of the Shelbyville Moraine, the terminal moraine of the Wisconsin glacier. Due to the relatively long period of time since glaciation, much of the area has been dissected by the down-cutting of streams, forming steep-sided ravines and deep valleys. Along many of the streams which run through or border the preserve are numerous sandstone outcroppings and steep hillsides that are over 50 feet from the base to the top.

The preserve contains remnants of the typical forest associated with the deep valleys of the Illinoian till of East-Central Illinois. The plants of the sandstone cliffs and the vegetation of the slopes and ravines make this an extremely interesting area botanically. Here exist some species that are not common to this part of Illinois. A few taxa that are mostly restricted to southern Illinois are found in the preserve. Included in this group are *Agrostis elliottiana, Collinsonia canadensis, Liatris scabra, Luzula bulbosa, Mitchella repens,* and *Panicum dichotomum.* Other plants common to only northern and/or western Illinois are also found at Rocky Branch. In this group are *Bartonia virginica, Corallorhiza odontorhiza, Goodyera pubescens, Helianthemum bicknellii, Ilex verticillata, Lechea villosa, Mitella diphylla, Osmunda claytoniana,* and *Viburnum acerifolium.*

Due to the many plants that are at the extreme edge of their range, or are well beyond their normal range, a number of botanists have studied the Rocky Branch area. Extensive studies of the Bryophytes were undertaken by Vaughan (1941) and later by Arzeni (1947). A study of the vascular plants was conducted by Stover (1930) who listed the common plant associations as well as many of the species he found in the area. Most of the taxa listed by Stover were also found during the present study, the most notable exception being the ground pine (*Lycopodium lucidulum*) which is probably now extinct in the area.

During the growing seasons of 1967 and 1968 the authors under-

took a study of the vascular plants of the Rocky Branch Nature Preserve. As a result of this study a total of 445 species of vascular plants in 97 families was found growing in the preserve. Of the species collected, 16 were fern or fern-allies, 97 were monocots, and 332 were dicots. Of this latter group, 80 were trees, shrubs or woody vines, while 252 were herbaceous. The largest family represented was the Compositae with 63 taxa, followed by the Gramineae with 53.

As a result of the present study, 120 taxa were found in the Rocky Branch Nature Preserve that have not been reported for Clark County, Illinois, by Jones and Fuller (1955) or by Winterringer and Evers (1960). In the following list of these new records the nomenclature follows that of Jones (1963). Each species is followed by a brief note concerning the habitat in which it was collected, the collector's name, and field number. All specimens are deposited in the herbarium of Eastern Illinois University.

Fern and Fern-Allies

EQUISETACEAE

Equisetum laevigatum A. Br. Sandy area near stream. Hellinga 65.

OPHIOGLOSSACEAE

Botrychium dissectum Spreng. Hillside thicket. Ebinger 9071.

Botrychium obliquum Muhl. Lowland woods. Hellinga 420.

Monocotyledoneae

AMARYLLIDACEAE

Hypoxis hirsuta (L.) Coville Upland open woods. Hellinga 156.

COMMELINACEAE

Commelina communis L. Sandy area near stream. Ebinger 8955.

CYPERACEAE

Carex artitecta Mack. Wooded hillside. Hellinga 124.

Carex gracilescens Steud. Lowland woods. Hellinga 43.

Carex hirtifolia Mack. Lowland woods. Ebinger 8241.

Carex sparganioides Muhl. Wooded hillside. Hellinga 465.

Cyperus acuminatus Torr. & Hook. Upland field. Ebinger 8653.

Eleocharis engelmannii Steud. Ditch in upland field. Ebinger 9123.

Eleocharis tenuis (Willd.) Schult. Ditch in upland field. Hellinga 187.

GRAMINEAE

Agrostis elliottiana Schult. Lowland woods. C. Brian (May, 1937).

Agrostis hyemalis (Walt.) BSP. Open woods. Ebinger 4220.

Aristida dichotoma Michx. Upland field. Hellinga 458.

Aristida longespica Poir. Upland field. Hellinga 515.

Dactylis glomerata L. Lowland field. Hellinga 247.

Festuca octoflora Walt. Wooded hillside. Hellinga 166.

Muhlenbergia frondosa (Poir.) Fern. Upland open woods. Ebinger 9291.

Muhlenbergia mexicana (L.) Trin. Lowland woods. Hellinga 473.

Muhlenbergia sobolifera (Muhl.) Trin. Upland open woods. Hellinga 446.

Muhlenbergia sylvatica Torr. Edge of road in ditch. Ebinger 7911.

Panicum boscii Poir. Wooded ravine. Ebinger 7358.

Panicum dichotomum L. Edge of woods and upland field. Ebinger 4449.

Panicum latifolium L. Lowland field. Ebinger 4447.

Panicum linearifolium Scribn. Upland open woods. Hellinga 240.

Panicum microcarpon Muhl. Lowland field. Ebinger 8983.

Phalaris arundinacea L. Lowland field. Ebinger 8243.

Sphenopholis obtusata (Michx.) Scribn. Lowlands woods. Ebinger 4457.

IRIDACEAE

Sisyrinchium bermudiana L. Lowland field. Hellinga 230.

JUNCACEAE

Juncus brachycarpus Engelm. Lowland field. Hellinga 273.

Juncus interior Wieg. Upland open woods. Hellinga 208.

Luzula bulbosa (Wood) Rydb. Upland field. Ebinger 7554.

LILIACEAE

Veratrum woodii Robbins. Upland woods. Ebinger 7361.

ORCHIDACEAE

Corallorhiza odontorhiza (Willd.) Nutt. Upland open woods. Hellinga 325.
Goodyera pubescens (Willd.) R. Br. Wooded hillside. Hellinga 455.
Liparis lilifolia (L.) Rich. Upland open woods. Hellinga 324.
Spiranthes vernalis Engelm. & Gray Upland open woods. Hellinga 457.

Dicotyledoneae

ACANTHACEAE

Ruellia strepens L. Lowland open woods. Hellinga 278.

AMARANTHACEAE

Amaranthus spinosus L. Sandy area near stream. Hellinga 477.

APOCYNACEAE

Apocynum cannabinum L. Upland field. Hellinga 267A.

ARALIACEAE

Aralia racemosa L. Rocky area in woods. Ebinger 4771.
Panax quinquefolius L. Upland woods. Ebinger 7366.

BORAGINACEAE

Cynoglossum virginianum L. Upland woods. Hellinga 55.

CALLITRICHACEAE

Callitriche terrestris Raf. Upland field. Ebinger 8220.

CAPRIFOLIACEAE

Viburnum acerifolium L. Shaded cliff face. Hellinga 210A.
Viburnum prunifolium L. Upland open woods. Ebinger 9086.

CARYOPHYLLACEAE

Cerastium vulgatum L. Edge of road. Hellinga 39.
Stellaria longifolia Muhl. Lowland field near stream. Hellinga 177.

CELASTRACEAE

Celastrus scandens L. Upland woods. Ebinger 9075.

CISTACEAE

Helianthemum bicknellii Fern. Upland field. Hellinga 448.
Lechea villosa Ell. Upland field. Hellinga 449.

COMPOSITAE

Antennaria plantaginifolia (L.) Hook. Upland woods and field. Hellinga 203.
Anthemis cotula L. Lowland thicket. Ebinger 4772.
Arctium minus (Hill) Bernn. Lowland thicket. Ebinger 9197.
Aster ontarionis Wieg. Sandy area at edge of creek. Hellinga 482.
Bridens cernua L. Sandy area at edge of creek. Hellinga 483.
Bidens comosa (A. Gray) Wieg. Sandy area at edge of creek. Ebinger 8961.
Boltonia recognita (Fern. & Grisc.) G. N. Jones. Upland field. Hellinga 344.
Cirsium altissimum (L.) Spreng. Lowland thicket. Hellinga 410.
Cirsium vulgare (Savi) Tenore. Edge of road in woods. Ebinger 7349.
Eupatorium fistulosum Barratt. Edge of road in ditch. Ebinger 7913.
Eupatorium sessilifolium L. Upland woods. Ebinger 7355.
Liatris scabra (Greene) K. Schum. Upland field. Hellinga 464.
Silphium perfoliatum L. Sandy area near creek. Hellinga 268.
Tragopogon dubius Scop. Edge of road in ditch. Ebinger 7557.
Verbesina helianthoides Michx. Lowland field. Hellinga 250.
Xanthium commune Britt. Upland field. Hellinga 367.

CONVOLVULACEAE

Cuscuta gronovii Willd. Parasite on *Solidago* at edge of creek. Ebinger 8981.

CRUCIFERAE

Brassica nigra (L.) Koch. Lowland field. Hellinga 69.
Hesperis matronalis L. Edge of road in shaded ditch. Ebinger 8219.
Sisymbrium officinale (L.) Scop. Lowland thicket. Hellinga 315.

CUCURBITACEAE

Sicyos angulatus L. Lowland woods. Ebinger 8967.

ERICACEAE

Monotropa lanuginosa Michx. Upland open woods. Ebinger 8618.
Monotropa uniflora L. Wooded hillside. Ebinger 8501.

EUPHORBIACEAE

Acalypha rhomboidea Raf. Upland field. Ebinger 9126.

GENTIANACEAE

Sabatia angularis (L.) Pursh. Upland field. Hellinga 266.

HYDROPHYLLACEAE

Hydrophyllum virginianum L. Lowland woods. Hellinga 162.

HYPERICACEAE

Hypericum gentianoides (L.) BSP. Upland field. Hellinga 451.

JUGLANDACEAE

Carya glabra (Mill.) Sweet. Upland woods. Ebinger 9191.

Juglans cinerea L. Lowland woods. Ebinger 4774.

LABIATAE

Lycopus virginicus L. Edge of creek. Ebinger 8963.

Perilla frutescens (L.) Britt. Lowland open woods. Ebinger 9193.

Scutellaria incana Biehler. Lowland woods. Hellinga 81.

Scutellaria lateriflora L. Lowland woods near creek. Ebinger 8962.

LEGUMINOSAE

Cassia hebecarpa Fern. Lowland field. Ebinger 4770.

Desmodium cuspidatum (Muhl.) Loud. Upland open woods. Ebinger 7354.

Lespedeza procumbens Michx. Upland field. Hellinga 501.

Lespedeza striata (Thunb.) H. & A. Upland field. Hellinga 502.

Lespedeza virginica (L.) Britt. Upland field. Ebinger 8652.

LYTHRACEAE

Ammannia coccinea Rottb. Ditch in upland field. Ebinger 9124.

MORACEAE

Morus rubra L. Lowland woods. Ebinger 9095.

OLEACEAE

Fraxinus americana L. Lowland woods. Ebinger 9097.

ONAGRACEAE

Circaea latifolia Hill. Lowland woods. Hellinga 86.

PLANTAGINACEAE

Plantago aristata Michx. Upland field. Hellinga 255.

Plantago virginica L. Upland open woods. Ebinger 4459.

POLYGONACEAE

Polygonum persicaria L. Edge of road in woods. Ebinger 7338.

Polygonum sagittatum L. Lowland thicket. Hellinga 375.

Rumex crispus L. Edge of road in ditch. Hellinga 216.

Rumex obtusifolius L. Lowland woods. Ebinger 7328.

PRIMULACEAE

Lysimachia nummularia L. Edge of creek in shaded area. Ebinger 8965.

ROSACEAE

Agrimonia rostellata Wallr. Lowland woods. Hellinga 296.

Crataegus calpodendron (Ehrh.) Medic. Lowland woods. Ebinger 9105.

Malus pumila Mill. Upland open woods. Ebinger 9289.

Prunus persica (L.) Batsch. Near abandoned dwelling. Ebinger 7985.

Rosa blanda Ait. Edge of road in woods. Ebinger 7352.

Rosa multiflora Thunb. Upland field. Ebinger 9120.

Rubus flagellaris Willd. Lowland field. Ebinger 8247.

Rubus occidentalis L. Lowland field. Ebinger 8246.

SALICACEAE

Populus grandidentata Michx. Upland field. Ebinger 9114.

Salix rigida Muhl. Edge of creek. Ebinger 7981.

SANTALACEAE

Comandra umbellata (L.) Nutt. Upland open woods. Hellinga 201.

SOLANACEAE

Datura stramonium L. Edge of creek in sunny area. Hellinga 267.

Lycium halimifolium Mill. Near abandoned dwelling. Hellinga 412.

Solanum nigrum L. Edge of creek in sunny area. Ebinger 8950.

UMBELLIFERAE

Erigenia bulbosa (Michx.) Nutt. Lowland woods. Ebinger 7435.

Osmorhiza longistylis (Torr.) DC. Lowland woods. Hellinga 161.

Sanicula gregaria Bickn. Lowland woods. Ebinger 8233.

VIOLACEAE

Viola eriocarpa Schw. Lowland woods. Hellinga 132.

Viola sororia Willd. Lowland field. Hellinga 22.

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VARIABLE EXPRESSION OF HI-FIN, A MUTATION IN *XIPHOPHORUS HELLERI* (PISCES: POECILIIDAE)

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ABSTRACT.—Hi-fin, a dominant mutation with recessive lethal effects, produces an oversized dorsal fin in the swordtail (*Xiphophorus helleri*). It is not apparent at birth but was found to be distinguishable about 33 days after birth. Hi-fin was shown to be directly associated with an increased rate of gonopodial development in males. Hi-fin males first begin to develop a gonopodium at an average of 136 days of age while low-fin males begin gonopodial development at an average age of 167 days. Sexual dimorphism in expression of dorsal fin shape was demonstrated and found to be enhanced by the presence of the hi-fin gene. The possibility of the existence of one or more modifiers is discussed but was not shown by the data presented.

Xiphophorus helleri, the swordtail, has long been used as a laboratory animal for studies of genetics. A great many mutations have been investigated in this fish (Gordon, 1937, 1938, 1946, 1953 and Kallman and Atz, 1966). One of the most recently discovered is hi-fin, a mutation which manifests itself phenotypically as an abnormally long dorsal fin. Hi-fin is a dominant gene with recessive lethal effects (Norton, 1967). The present study was initiated to investigate the relationship of this mutation to sexual development and variable expression of dorsal fin shape.

MATERIALS AND METHODS

Genetic crosses were made between fish which carried the phenotypic markers hi-fin, *H,* and low-fin, *H+*, using a breeding stock which was obtained from a pet store in San Diego. Offspring from this stock were used in all subsequent matings.

Because *X. helleri* females can store sperm for long periods of time virginity of females used in all matings was necessary. Physical contact must be made between male and female in order for insemination to occur, consequently, the gonopodium must have a series of hooks or holdfasts developed on the end (Rosen and Bailey, 1963). In young fish the first indication that a gonopodium is developing is the thickening and lengthening of anal rays 3, 4, and 5, with the holdfasts developing later. Removal of males from the rearing tanks when the anal rays indicated gonopodial development assured the virginity of females used in the crosses.

Offspring were scored for fin type, sex, age in days at the first appearance of the hi-fin, and the age in days at which males first developed a recognizable gonopodium. An individual was scored as a male only if anal rays 3, 4, and 5 had elongated and thickened enough to be recognized as a developing gonopodium. Fish were observed daily for removal of recognizable males. Fin type was determined by observation and individuals were scored as hi-fin or low-fin. Total body length was meas-

ured from the snout to the posterior edge of the caudal fin, not including the sword extension of the males. The height of the third anterior, the second posterior and fifth posterior dorsal rays was measured in two of the groups after they reached sexual maturity. A group of fish is the product of a single mating and all data from single groups were kept separately. Ninety-seven percent of the males were recognizable before the age of 240 days. For clarity sexually mature fish are defined here as fish 240 or more days of age.

The age of appearance of the gonopodium was compared between groups with no attention to the fin type. This comparison was made using the Kruskal-Wallis Rank Test (Steel and Torrie, 1960). Then all groups were combined and the age of gonopodial appearance was compared between hi-fins and low-fins. The Mann-Whitney U Test (Steel and Torrie, 1960) was used for this calculation.

The regression of the height of each of the three dorsal rays on the body length of the fish was compared using a two by two analysis of covariance (Steel and Torrie, 1960). This analysis allows for the comparison of the dorsal rays, both between sexes and between groups, using one ray at a time. Thus the length of the third anterior dorsal ray of the hi-fin males in groups 1 and 2 was compared to the length of the third anterior dorsal ray of the hi-fin females in groups 1 and 2. Also at the same time, this ray of the hi-fin males and females in group 1 was compared with the third anterior ray of the hi-fin males and females in group 2. This analysis was repeated for each of the three measured rays using hi-fins and then for each of the three rays using the low-finned fish of the same two groups.

Results and Discussion

The hi-fin is not apparent at birth. It first appears at an average age of 33 days as an elongation of the third dorsal ray, and then the entire fin grows to a much larger size than that of the low-fin.

All groups that were scored after sexual maturity were used in tests for differences in rate of gonopodial development. Disregarding fin type these groups were tested for differences in rate of gonopodial development between groups and no significant difference could be detected ($P = .15$). Since these groups were homogenous they were combined and the rate of gonopodial development was compared between hi-finned and low-finned males. The probability that there was no difference in the rate of gonopodial development between hi-finned and low-finned males was less than .001 indicating a difference in the rate of development associated with fin type. The average age of first appearance of the gonopodium in hi-finned males was 136 days and in low-finned males was 167 days indicating that the hi-fin mutation was associated with an increased rate of development of this secondary sexual characteristic.

In the individuals carrying the hi-fin marker it was apparent that there was a difference of expression between males and females. The dorsal rays of males carrying hi-fin

were lengthened in all parts of the fin (Fig. 1A). The dorsal rays of the hi-fin females were not as long in proportion to the body as the dorsal rays of the males (Fig. 1B and 1C). In the female the posterior rays were shorter than the anterior rays while in the males the central rays were the longest. To a lesser extent this sexual dimorphism could also be observed in the low-finned fish (Fig. 1D and 1E).

These differences in dorsal ray length were compared statistically. Group 1 (H x H) was compared to group 2 (H x +) to see if this sexual dimorphism could be described mathematically. It was found that in hi-fins there was a significant difference of expression between sexes in all three of the measured rays, the third anterior, second posterior, and fifth posterior. The probability that there was no difference between sexes was less than .005 for all three dorsal rays. In low-fins this difference was detectable only in the second and fifth posterior rays with the probability of no difference being less than .005 in both cases. The probability of no difference for the third anterior ray between sexes in the low fins was greater than .05. There was also a significant difference in all three of the rays between groups for both hi-fin and low-fin ($P < .005$). This indicates that there is a sexual effect on the expression of fin shape that was more noticeable and variable when associated with hi-fin. The differences between groups may have been due to differences in sex-ratio between the groups or to the presence of one or more modifying genes acting on the expression of hi-fin. Probably a combination of both causes would be the best explanation of these differences and would indicate the necessity of further crosses involving this mutation.

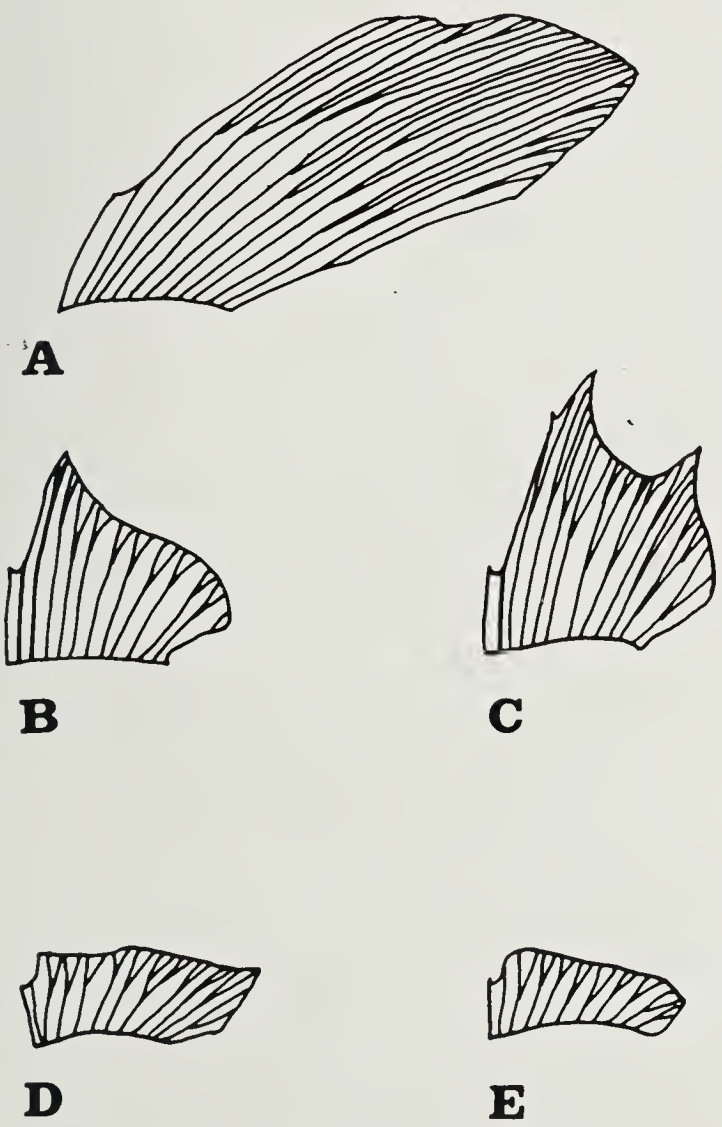

FIGURE 1. Dorsal fins of *Xiphophorus helleri*. A. Male hi-fin, B and C. Female hi-fin, D. Male low-fin, E. Female low-fin.

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THE GROWTH OF PONDEROSA PINE IN ILLINOIS LIMITED BY THE NEEDLE BLIGHT

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ABSTRACT.—For the purpose of testing the adaptability of ponderosa pine for forest planting in Illinois, 9 seed origins (1 each from Nebraska, North Dakota, and Montana and 2 each from Colorado, Idaho, and Oregon) provided planting stock for 21 plantations in 6 counties in 1941 and 1942. At age 20, the needle blight (*Scirrhia pini*, Funk and Parker) caused more than 90 percent mortality in 12 of the 21 plantations, and 5 years later, 8 of the remaining 9 plantations had reached or were entering this stage of infection. The early growth of ponderosa pine was exceeded by red, white, and jack pines in northern and central Illinois, and by loblolly, shortleaf, and Virginia pines in southern Illinois.

One of the goals of a newly created Department of Forestry, University of Illinois, in 1938 was to determine the growth potential and usefulness of a number of forest tree species for planting in Illinois. Because of its extensive geographic range which takes it through a wide variety of topographic and climatic features, ponderosa pine (*Pinus ponderosa* Laws.) was one of the species chosen for this study. It is the most widely distributed pine in western North America, extending from southern British Columbia in the north to mid-Mexico in the south. In the United States it occurs in commercial quantities in every state west of the Great Plains and is generally found in a subhumid humidity province characterized by a summer rainfall deficiency. The early results of this study, involving 9 seed sources of ponderosa pine, were summarized by Lorenz (1949). A number of studies pertaining to racial or ecotypic variation in ponderosa pine showed differences in survival, growth, and morphological characteristics of foliage (Weidman, 1939; Munger, 1947; Mirov *et al.*, 1952; and Squillace and Silen, 1962). From the data provided by two ponderosa pine provenance studies conducted in northern Idaho (45 years old) and in Oregon and Washington (30 years old), Squillace and Silen (1962) found that trees which grew most rapidly came from seed origins located where precipitation and temperature patterns matched the climatic pattern of their planting sites. Altitudinal races were reported by Mirov *et al.* (1952). More recently the North Central Forest Tree Breeding Committee, NC-51, in cooperation with the United States Forest Service, established an 80-origin seed source study of ponderosa pine in 8 states and 2 Canadian provinces (unpublished committee report 1968).

Illinois extends 385 miles from north to south, approximately one-third the distance between the Canadian border and the Gulf of Mexico. Native conifers are very sparsely represented in Illinois. Eastern red cedar (*Juniperus virginiana* L.) is the only native conifer with statewide distribution. Three northern

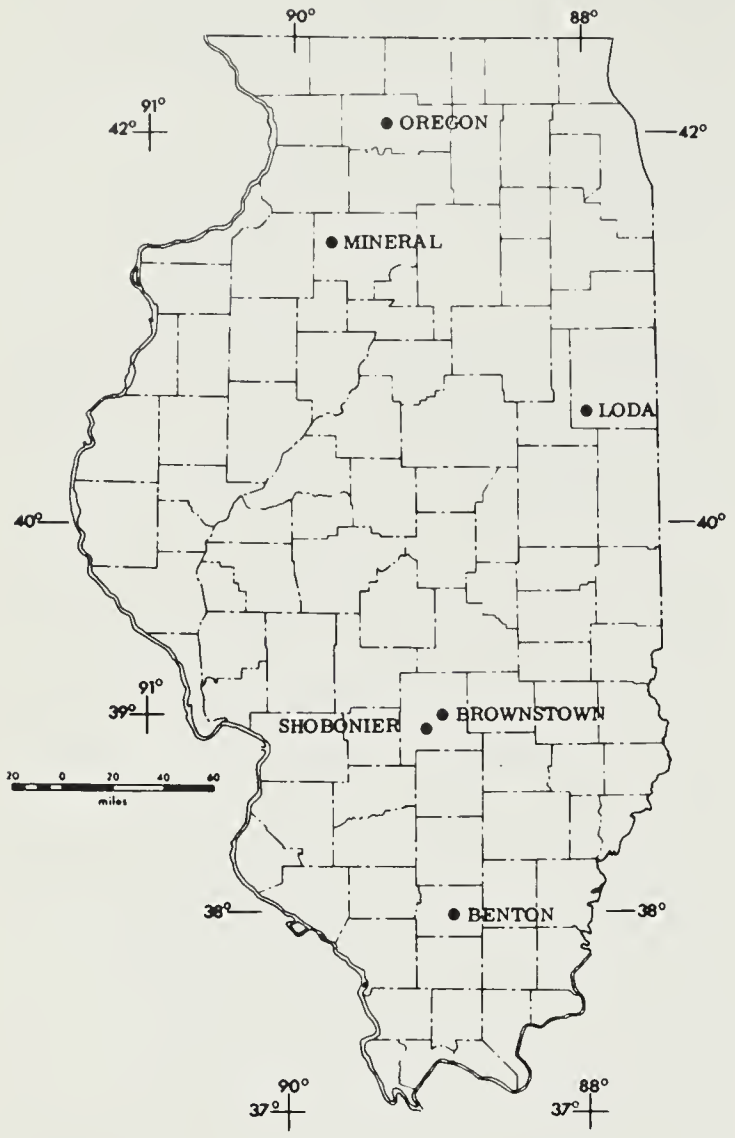

FIGURE 1. Location of ponderosa pine plantations established for species adaptation study.

conifers occur naturally in northern Illinois and two southern conifers are native to its southern tip. Moisture is seldom a limiting factor for tree growth in Illinois. Approximately 60 percent of the annual precipation occurs during the growing season. The average annual precipitation in Illinois increases from 32 inches in the north to 46 inches in the south.

THE NEEDLE BLIGHT OF PONDEROSA PINE

Robert L. Hulbary (1941) described a previously unnamed needle blight (*Dothistroma pini* Hulbary) found on Austrian pine (*P. nigra* Arnold) in northern Illinois, and Funk and Parker (1966) described its perfect state and named it *Scirrhia pini.* Previous to this time, long standing confusion had existed in the taxonomic literature with regard to the separation of the species in the genus *Scirrhia,* especially between *S. pini* and the brown spot needle blight of southern pine (*S. acicola* (Dearn) Siggers). Peterson (1965) reported that the *D. pini* blight was causing serious damage to Austrian and ponderosa pine in windbreak, ornamental, and Christmas tree plantings in the central and southern Great Plains (Nebraska, Kansas, and Oklahoma). Carter (1967, p. 9) made the following statement to the Indiana Arborist Association meeting:

> "This leaf disease, caused by the fungus *Dothistroma pini,* is widespread in the United States, Canada, Chile and Kenya."

He briefly described the disease as follows:

> "Symptoms of the disease appear in late summer as slightly swollen, dark spots or bands on one-year-old and older needles. On some pines the banded areas become red — a condition referred to as 'red-banding.' The part of a diseased needle from the swollen and discolored area to the tip turns light brown and dies."

In an appraisal of the needle blight in California, Wagener (1967, p. 4) stated that

> "The speed with which the red band blight became established in new centers around the world is probably unparalleled in the history of tree diseases."

He also stated that the disease has been reported on about 30 species, varieties, or hybrid pine. Dr. J. C. Carter and Dr. D. F. Schoeneweiss, plant pathologists at the Illinois Natural History Survey, have, on the basis of field and laboratory observations, confirmed that identification

of the needle blight on ponderosa pine plantations throughout Illinois as *Scirrhia pini* Funk and Parker.

Seeding and Planting

Nine seed sources were used to establish the 21 plantations comprising this study, eight were furnished by the United States Forest Service, and one came from a commercial seedhouse. The locations and altitudes of the seed origins are given in Table 1. Field plantings were made at 6 locations from northern to southern Illinois as shown on the map (Fig. 1). Each of the 9 sources was represented by a single block planting at 1 to 4 of the locations, but unfortunately replicated plantings were not made at all locations from all seed sources. The size of the average planting was one-third of an acre comprising 413 trees; the smallest planting contained 174 trees, and the largest planting 1,225 trees. Seed from the four sources obtained in 1939 (Colorado; Idaho City, Idaho; Bend and LaPine, Oregon) were grown in the Union State Tree Nursery in southern Illinois and were planted in the spring of 1941 as 2-0 seedlings in 6 x 6 foot spacings. Similar treatment was given to the 5 seed sources obtained in 1940 (Halsey, Nebraska; Medora, North Dakota; Pueblo, Colorado; Missoula, Montana; and McCall, Idaho) except that they were grown in the Mason State Tree Nursery in central Illinois and planted in the spring of 1942. The plantings were made on old fields which had not been cultivated for a number of years. The fields at Loda and Shobonier were severely eroded. The soil descriptions for the planted areas as described by Wascher *et al.* (1950) are as follows: Oregon, Bloomfield fine sand; Mineral, Plainfield sand; Loda, Chatsworth silt loam; Brownstown, Bluford and Wynoose silt loam; Shobonier, Hickory loam; and Benton, Hickory loam with some Ava and Bluford silt loam. Survival was excellent in the early years, except at Mineral, where volunteer sweet clover, fires, and theft took their toll. At age 10 a release cutting was made in several of the plantings at Benton and in two plantings at Brownstown.

Table 1.—Location and altitude of ponderosa pine seed origins.

State	City	National Forest	Latitude	Longitude	Altitude, Feet
Nebraska	Halsey	Nebraska	41° 52′	100° 20′	2,600
North Dakota	Medora		46° 50′	103° 36′	2,900
Colorado	Pueblo	San Isabel	38° 20′	105° 10′	7,000
Colorado					
Montana	Missoula	Lolo	46° 48′	114° 5′	3,500
Idaho	Idaho City	Boise	43° 48′	115° 45′	4,300
Idaho	McCall	Fayette	44° 50′	116° 8′	5,000
Oregon	Bend	Deschutes	44° 0′	121° 20′	3,950
Oregon	LaPine	Deschutes	43° 44′	121° 36′	3,830

Results

The Needle Blight

The needle blight did not manifest itself to a noticeable degree until after the 5-year measurements were made. Annual measurements were not made between the ages of 5 and 10, but at age 10, 13 of the 21 plantations showed noticeable infection with incidence ratings varying from 1 through 3. Seven numerical classes were employed to describe the incidence of needle blight as follows:

0—not apparent
1—incipient stages
2—light—lower foliage whorl dead
3—moderate—25 to 50 percent of foliage dead
4—heavy—50 to 75 percent of foliage dead
5—severe—75 to 90 percent of foliage dead
6—more than 90 percent of the trees dead

The trees in any one plantation responded quite uniformly in the manner and rate at which the infected foliage died progressively upward from the bottom whorl to the tip (Fig. 2). Twelve of the 21 plantations had more than 90 percent mortality at age 20. Growth data were not taken at age 25, but an appraisal of the needle blight incidence showed that 8 of the 9 remaining plantations were entering or had reached the 90 percent mortality stage. The numerical ratings for the incidence of needle blight are given in Table 2. In general, at the same locations and on similar planting sites, the plantations originating from seed west of the Continental Divide showed a higher incidence of needle blight than those whose seed originated east of the Continental Divide.

Figure 2. A severe infection of needle blight on ponderosa pine, age 15, at Benton, Illinois. The seed source was from the Deschutes National Forest in Oregon.

Diameter and Height Growth

Diameter and height growth for the 21 plantations are given in Table 2 for ages 5, 10, 15, and 20. Although growth data were confounded by the needle blight, several comparisons should be given. Seeds from the Missoula area at an altitude of 3,500 feet in the Lolo National Forest produced trees with the greatest height at age 15, both in the northernmost and southernmost planting locations. Also at age 15, very little difference in heights was noted between the plantations originating from seed west of the Continental Divide and those originating from seed east of the Continental Divide.

TABLE 2.—Performance of ponderosa pine seed sources at ages 5, 10, 15, and 20 years in Illinois plantations.

Location of Plantation and Seed Origin	Survival				Mean D.B.H.				Mean Height				Incidence of Needle Blight			
	5	10	15	20	5	10	15	20	5	10	15	20	5	10	15	20
	Percent				Inches				Feet							
Oregon, Ogle County																
Nebraska, Halsey	57	56	56	33	....	1.9	3.5	4.8	2.8	9.2	16.4	25.0	0	1	3	5
North Dakota, Medora	87	87	85	77	....	2.1	3.9	4.9	3.2	10.8	20.1	29.4	0	0	2	4
Colorado, Pueblo	98	98	97	77	....	1.8	3.6	4.8	2.6	7.3	16.9	22.2	0	1	2	4
Colorado	89	87	86	73	....	2.0	3.5	4.8	3.1	9.6	17.6	24.6	0	1	2	3
Montana, Missoula	84	82	79	....	....	2.6	4.2	....	3.5	11.4	20.3	.....	0	2	5	6
Idaho, Idaho City	84	71	69	....	....	2.3	3.5	....	3.0	9.7	16.0	.....	0	1	5	6
Idaho, McCall	80	76	65	....	....	2.4	4.0	....	3.2	10.3	16.7	.....	0	3	5	6
Oregon, Bend	94	91	88	....	....	2.7	4.0	....	3.9	11.5	18.4	.....	0	3	5	6
Mineral, Bureau County																
Colorado	17	12	9	7	....	1.6	4.8	7.2	2.1	7.5	15.6	23.2	0	0	0	1
Loda, Iroquois County																
Nebraska, Halsey	67	56	55	30	....	0.4	1.8	3.1	1.4	4.5	9.1	14.6	0	0	0	2
Brownstown, Fayette County																
Nebraska, Halsey	87	87	86	11	....	1.2	2.7	....	2.2	7.1	14.3	.....	0	0	3	6
Colorado, Pueblo	88	87	86	65	....	1.2	2.7	3.7	2.0	6.6	13.5	20.8	0	0	2	5
Shobonier, Fayette County																
Colorado, Pueblo	87	42	42	18	....	1.2	3.4	4.1	2.0	6.4	14.1	23.5	0	0	2	5
Montana, Missoula	84	67	25	....	....	1.7	3.0	....	2.4	8.5	15.6	.....	0	2	5	6
Benton, Franklin County																
Nebraska, Halsey	97	32	31	....	....	1.6	3.1	....	2.8	8.5	16.1	.....	0	0	3	6
Colorado, Pueblo	89	23	21	....	....	1.1	2.5	....	2.1	6.2	12.1	.....	0	2	3	6
Colorado	93	93	93	64	....	1.5	3.1	4.2	3.1	7.5	14.5	20.6	0	0	3	5
Montana, Missoula	96	89	28	....	....	1.9	3.1	....	3.3	9.0	16.8	.....	0	2	5	6
Idaho, Idaho City	92	88	51	....	....	1.6	3.0	....	2.7	7.8	13.6	.....	0	3	5	6
Oregon, Bend	92	92	79	....	....	1.7	3.3	....	2.8	8.2	14.8	.....	0	3	5	6
Oregon, La Pine	99	98	80	....	....	1.8	3.1	....	3.0	8.3	13.5	.....	0	1	5	6

Discussion

There was some evidence that a more protected site with its shade and reduced wind velocities may predispose ponderosa pine to the needle blight. Ponderosa pine plantations established at Mineral and Benton with trees from the same seed source (Colorado) showed noticeable differences with respect to needle blight infection with incidence ratings of 1 and 5, respectively, at age 20. The trees at Mineral were open-grown on a dry, sandy knoll with adequate air drainage (Fig. 3); those at Benton were on a more protected site with heavy soil, more shade, and reduced wind velocities. Although not part of

Figure 3. This 27-year-old plantation of ponderosa pine is unique because it has not succumbed to the needle blight. It was established from Colorado seed on a well-exposed site of drifting sand (Plainfield) near Mineral.

this original study, the light infection of 2 33-year-old ponderosa pine plantations on dry, prairie, sand knolls in Mason County also supported this contention. These observations support those of Van Haverbeke and Bolt (1968), who stated that released ponderosa pine in eastern Nebraska shelterbelts showed less infection than those that were not released. They suggested that the heavy shade and reduced wind velocities inside the untreated segments created a slightly more moist atmosphere which favored the germination of the spores and subsequent growth of the fungus. Rogerson (1954) noted that during the rain-deficient year of 1952 in Kansas, there was no new development of *Dothistroma* needle blight, whereas during the wet year of 1951, incidence of the disease increased markedly. Lack of replication did not permit statistical analysis of the data; neverthless, the significant role of the needle blight was demonstrated by the fact that at age 25, 20 of the 21 plantations had more than 90 percent mortality or were entering this stage of infection.

The early growth of ponderosa pine on light soils in northern Illinois compared favorably with that of red pine (*Pinus resinosa* Ait.) but was greatly exceeded by that of jack pine (*Pinus banksiana* Lamb.). At age 5, 8 separate seed sources of ponderosa pine on Bloomfield fine sand near Oregon, in north-central Illinois, had a combined mean height average of 3.2 feet, while adjacent red and jack pine plots of the same age had average mean heights of 3.3 and 7.2 feet, respectively. Likewise, the early growth of red, white (*Pinus strobus* L.), and jack pine exceeded that of ponderosa pine on most sites in central Illinois, and in southern Illinois loblolly pine (*Pinus taeda* L.), shortleaf pine (*Pinus echinata* Mill.), and Virginia pine (*Pinus virginiana* Mill.) far surpassed that of ponderosa pine, Lorenz (1949).

Summary and Conclusions

For the purpose of testing the adaptability of ponderosa pine for forest planting in Illinois, 9 seed origins (1 each from Nebraska, North Dakota, and Montana and 2 each from Colorado, Idaho, and Oregon) provided planting stock for 21 plantations in 6 counties in 1941 and 1942. Each of the 9 sources was represented by a single block planting at 1 to 4 of the 6 locations. The needle blight determined the fate of all but one of the 21 plantations. Twelve of the original 21 plantations had more than 90 percent mortality at age 20, and 5 years later 8 of the remaining 9 had reached or were entering this degree of infection. There was some evidence that the more open and exposed plantings on sandy soils showed a lower incidence of needle blight due to a drier habitat. The early growth of ponderosa pine was generally exceeded by red, white, and jack pine in northern and central Illinois and by loblolly, shortleaf, and Virginia pine in southern Illinois. In order to minimize damage from the needle blight disease, the forest planting of ponderosa pine in Illinois should be confined to the dry, sandy knolls with adequate air

drainage such as those found in Bureau, Cass, Henderson, and Mason counties.

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MOVEMENTS OF *MYOTIS LUCIFUGUS LUCIFUGUS* FROM A COLONY IN LASALLE COUNTY, ILLINOIS

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Abstract. — The movement pattern of *Myotis lucifugus* banded at Blackball Mine, 1.75 miles West of Utica, LaSalle Co., Illinois during winter, and recovered elsewhere during the summer is summarized. Dispersal is shown to be closely correlated with the Illinois River waterway. Data on distance traveled, seasonal movement, and degree bearing are recorded for both *M. lucifugus* and *M. sodalis*.

Considerable scientific literature reporting homing ability and possible use of vision in orientation of bats has been published in the past decade. Few studies regarding routes of travel, and nothing regarding seasonal migration of *Myotis lucifugus* in Illinois have been reported.

The possible use of rivers as flyways for bats has been postulated by Hall (1962) for *Myotis sodalis* in Illinois, Indiana and Kentucky. Humphrey & Cope (1964) hypothesize that *M. lucifugus* follows a route along the line of caves in which they hibernate in southern Indiana. Hassell & Harvey (1965) in testing Hall's idea postulate that waterways as routes of travel for *M. sodalis* taken in Kentucky, and released in Ohio, North Carolina, and Kentucky are not necessary for successful homing.

The present study was primarily concerned with migration, although it yielded other information on the winter population of this species.

Methods and Materials

From 1961-1968, over 12,000 bats, of which 7,873 were *M. lucifugus* were banded at Blackball Mine, 1.75 miles west of Utica, LaSalle Co., Illinois. The majority of the visits were made from fall to spring, although occasional visits were made during the summer months. The commonly used band was No. 2, furnished by the U.S. Fish and Wildlife Service. A few 1-B bands were also used at the beginning of this project.

For each bat the path traversed was plotted as a straight line distance between the colony and point of recapture. This line denotes the direction of movement, although there is no implication that this is the actual route followed by the bat. Spring and fall recoveries are pooled, as no differences in flight pattern are apparent.

For each recovery the degree bearing was tested by using the Rayleigh Test (Batschelet, 1965) with a cut-off criterion of $P = 0.1$. Mean direction ϕ, and mean angular deviation, S, were calculated by vector analysis (Batschelet, *ibid*).

Observations

Blackball Mine was mined by the Illinois Hydraulic Cement Manufacturing Company in the early 1900's.

The mine covers approximately 40 acres of subterranean passages (Hall, 1962), with entrances facing north, south and west.

The Illinois River closely parallels Blackball Mine, and from its origin, fifty-miles southwest of Chicago, flows almost due west (270° mean direction) for some sixty miles, to a point not far from Hennepin, where it turns abruptly, flowing southwest by south a hundred and sixty-five miles (220° mean direction) to its union with the Mississippi (Pickels & Leonard, 1929).

Females are the first to leave Blackball Mine in Spring. The exodus begins about the third week in April, and appears fairly rapid, as males represent 85-94% of the remaining population during May and early June. This closely agrees with Davis & Hitchcock (1965) and Barbour & Davis (1969) for the New England States.

The recovery rate of *M. lucifugus* banded in winter and recovered in summer is low. Of 7,873 (plus 841 banded by Dr. Wayne H. Davis in 1954) banded at Blackball Mine in winter, only 38 were recovered in summer, Table 1). This can be accounted for by not having found summer colonies within north-central Illinois. All recoveries are based on reports submitted by private individuals to the U. S. Fish & Wildlife Service. These returns varied from 2 miles to 105 airline miles, the average distance being approximately 25.6 miles.

The average minimum age of bats recovered was 2 years and the greatest minimum age was 11.7 years, in a specimen banded by Wayne H. Davis, 2 February 1954, and recovered at Henry, Marshall County, Illinois in August 1965, 24 miles from the place of banding.

Rather than dispersing generally over Illinois, *M. lucifugus* banded at Blackball Mine disperse in a fairly direct west southwest to south-southwest pattern. This pattern is closely correlated with the Illinois River watershed (Fig. 1).

Of the 38 recoveries one was taken outside the Illinois River watershed. This was a male banded 11 May 1963, and recovered 12 miles north of Mt. Carroll, Jo Daviess, 14 July 1964, within the Mississippi River drainage system. Two additional recoveries from Ottawa, LaSalle Co., and one from Marseilles, LaSalle Co., are within the 90° bearing, also corresponding with the Illinois River watershed.

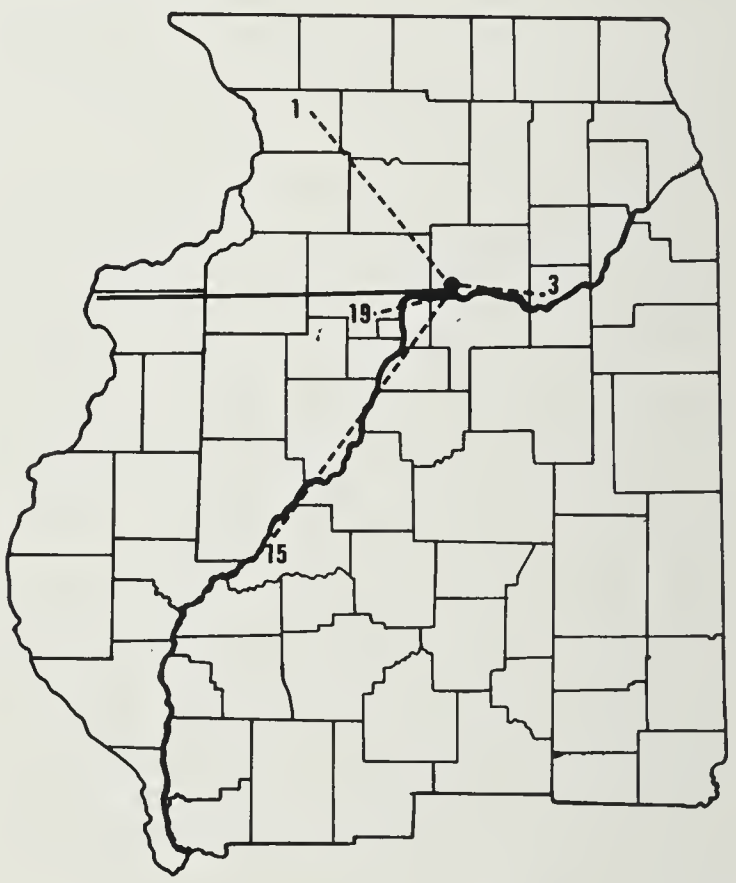

FIGURE 1. Movement pattern of 38 *Myotis lucifugus* banded in winter at Blackball Mine, LaSalle Co., Illinois, and recovered in summer. Numbers represent number of individuals taken at each recovery site. Double line represents Illinois-Michigan Canal, while solid line denotes the Illinois River.

TABLE 1.—Bat Recoveries.

Band No.	Date Banded	Date Recovered	Locality	Age	Distance Traveled	Sex
East:						
60278662	10–20–63	10–00–64	Ottawa, LaSalle Co.	1 yr.	10 mi.	M
60223024	10–22–61	09–07–67	Ottawa, LaSalle Co.	6 yrs.	10 mi.	M
64273983	11–08–64	09–00–65	Marseilles, LaSalle Co.	1 yr.	17 mi.	M
Northwest:						
60223913	05–11–63	07–14–64	Mt. Carroll, Jo Daviess Co.	1 yr.	75 mi.	M
West South West:						
05490379	02–20–54	08–28–64	Tiskilwa, Bureau Co.	10 yrs.	26 mi.	M
64273552	11–07–64	04–25–64	LaSalle, LaSalle Co.	1 yr.	2 mi.	M
00714133	10–18–68	09–00–69	LaSalle, LaSalle Co.	1 yr.	2 mi.	F
00713772	10–18–68	07–24–69	LaSalle, LaSalle Co.	1 yr.	2 mi.	M
00714991	10–18–68	04–30–69	Hennepin, Putnam Co.	1 yr.	18 mi.	F
64274362	10–20–63	06–04–69	Hennepin, Putnam Co.	6 yrs.	18 mi.	F
60223258	04–15–62	02–00–65	Hennepin, Putnam Co.	3 yrs.	18 mi.	M
64274033	10–20–63	09–16–65	Hennepin, Putnam Co.	2 yrs.	18 mi.	F
60223741	09–29–62	08–18–65	Hennepin, Putnam Co.	3 yrs.	18 mi.	M
64272239	11–09–63	02–16–64	Peru, LaSalle Co.	1 yr.	9 mi.	F
64274554	11–07–64	10–26–66	Peru, LaSalle Co.	2 yrs.	9 mi.	F
05419142	02–20–54	06–10–54	Washburn, Woodford Co.	4 mo.	33 mi.	M
60223202	11–05–61	09–23–63	Lake Depue, Bureau Co.	2 yrs.	16 mi.	F
64272759	11–10–63	06–15–64	Elmore, Peoria Co.	1 yr.	66 mi.	F
60278926	11–09–63	07–00–64	Putnam, Putnam Co.	1 yr.	21 mi.	M
64272563	11–09–64	07–00–65	Bureau, Bureau Co.	2 yrs.	18 mi.	M
60278612	10–20–63	08–16–65	Buda, Bureau Co.	2 yrs.	33 mi.	M
00549032	02–20–54	07–12–55	Bureau, Bureau Co.	1 yr.	18 mi.	M
60278252	05–11–63	06–02–63	Princeton, Bureau Co.	1 mo.	24 mi.	M
South South West:						
60223534	04–15–62	09–12–63	Lacon, Marshall Co.	1 yr.	30 mi.	F
64274744	11–07–64	05–15–66	Lacon, Marshall Co.	2 yrs.	30 mi.	F
60223822	09–29–62	10–17–63	Rome, Peoria Co.	1 yr.	42 mi.	F
64273496	11–07–64	05–00–66	McNabb, Putnam Co.	2 yrs.	15 mi.	M
60278629	10–20–63	06–14–64	McNabb, Putnam Co.	1 yr.	15 mi.	M
00713710	10–18–68	05–20–69	McNabb, Putnam Co.	1 yr.	15 mi.	M
60223582	04–22–62	08–23–62	Peoria, Peoria Co.	4 mo.	51 mi.	F
64274100	10–20–63	05–20–67	Peoria, Peoria Co.	4 yrs.	51 mi.	F
05419005	02–20–54	09–00–65	Henry, Marshall Co.	11 yrs.	24 mi.	M
64273478	11–07–64	06–09–65	Henry, Marshall Co.	1 yr.	24 mi.	M
06505365	04–22–62	08–23–62	Henry, Marshall Co.	4 mo.	24 mi.	F
60223319	02–04–62	05–30–62	Henry, Marshall Co.	3 mo.	24 mi.	M
00549008	02–20–54	05–03–54	Washburn, Marshall Co.	3 mo.	33 mi.	M
00713889	10–18–68	07–00–69	Bath, Mason Co.	1 yr.	105 mi.	F
00714706	10–18–68	08–22–69	Chillicothe, Peoria Co.	1 yr.	40 mi.	F

Two living bats recovered during February may possibly be explained by these bats wintering elsewhere, or possibly moderate weather during February of 1964-5 had some effect on the movement of these bats. Both localities, Hennepin, Putnam Co., and Peru, LaSalle Co., are within several hours flight from Blackball Mine, and easily traversed in an evenings flight. During May through July males represented 76

percent of the recoveries, which may be accounted for by the females being in established maternity colonies. During August recoveries were near the 50-50 ratio, while from September through October, females represented 61.5% of the recoveries. This can be accounted for by breaking up of maternity colonies, and movement becoming more leisurely. Also males are already returning to winter quarters during August and September (Fig. 2). This is in close agreement with Davis & Hitchcock (1965).

Previous studies on bat migration either show a northward movement in spring, or erratic pattern in any direction. Davis & Hitchcock (1965) found that the majority of the bats banded in Aeolus Cave, Vermont moved in a narrow southeastern pattern, although occasional individuals were recovered in all other directions except southwest. This is the first report of a southwestern movement pattern for *M. lucifugus* leaving winter quarters.

It is apparent that in this study there is a definite correlation between points of recovery and the Illinois River. Essentially all of the bats recovered were from WSW to SSW directions (Fig. 1) with three individuals deviating to the east, and one to the northwest. Due to the abrupt change in the course of the river, individuals were divided into two groups, those recovered from a WSW direction and those from a SSW direction. The WSW direction is correlated with the Illinois River flow to Hennepin (mean 270°) where it abruptly turns towards the SSW. Fifteen (39.5 percent) of 38 bats were recovered from this bearing. The mean angle, 261.93° is significant at the one percent level. Nineteen, 50 percent were recovered from a SSW bearing, with a mean angle 219.66°. The SSW individuals are correlated with the river flow from Hennepin to its mouth (mean 220°). The WSW and SSW bearings represent 89.5 percent of the recoveries. The mean direction for all recoveries 243.15° with an angular deviation of 24.7° also is significant at the one percent level (Table 2).

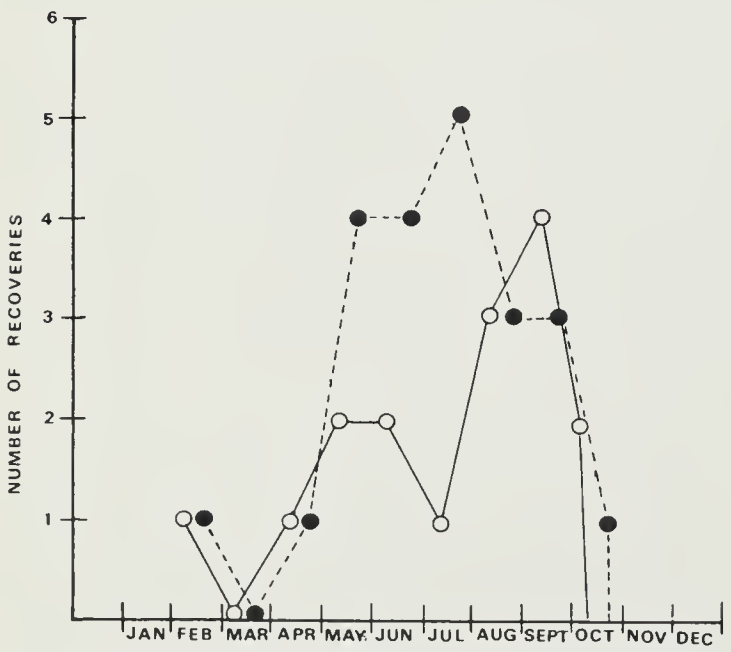

FIGURE 2. Monthly recoveries of *Myotis lucifugus* taken in Illinois. See text.

It is interesting to note that none of the recoveries is from known summer colonies, but apparently represents transitory individuals. All persons reporting recoveries were contacted, and replies reported only straggler individuals.

Hall (1962) reported on one specimen of *M. sodalis* banded at Blackball Mine, and recovered at Colossal Cave, Edmonson Co., Kentucky. This single report lends little support of the possible use of rivers as flyways for *M. sodalis* in Illinois. Another specimen of *sodalis* banded by the author at Blackball Mine,

TABLE 2.—Recovery directions of *Myotis lucifugus* correlated with the flow of the Illinois River.

	Entire Sample	S.S.W. Sample	S.W. Sample
No. of Recoveries	38	15	19
Mean Direction Ø	243.15°	219.66°	261.93°
Angular Deviation S	24.7 °	10.27°	15.82°
Rayleigh Test			
Z Value	27.97	14.52	17.57
P Value	.01	.01	.01

10 November 1963 was taken three years later at Palmyra, Marion Co., Missouri, 20 August 1966, 230° WSW, and 156 miles from the point of banding. Hall felt that no movement took place between Illinois populations of *M. sodalis* and the Ozark area of Missouri. The present recovery tends to show a greater dispersal pattern than was previously hypothesized.

The Illinois-Michigan Canal possibly also plays a significant role in migration of *M. lucifugus* and *M. sodalis*. Three recoveries of *lucifugus* from Tiskilwa, Buda, and Princeton, Bureau Co., Illinois, all border the canal, which also parallels the Illinois River, and extends to the Mississippi River. This would greatly aid *sodalis* in migration from Missouri, and possibly accounts for the small population of *sodalis* in Central Illinois.

Several other factors possibly play important roles in the dispersal pattern of *lucifugus* and *sodalis* in Illinois: 1) Less than one percent of northern Illinois is forested, and all this territory borders major streams. This affords adequate roosting sites for migrants. 2) Assuming that the first human communities in Illinois were established on major waterways, this would provide many older dwellings which are more suitable quarters for summer colonies. On straying away from major waterways in Illinois, bats would be confronted with miles of cultivated fields, and small communities consisting of relatively new homes which would not provide suitable roosting sites for summer colonies.

Topographic features have been shown to aid *M. lucifugus* during spring and fall migration in Indiana (Humphrey & Cope, 1964). In Illinois all major cave systems border major streams (Bretz & Harris, 1961), which would account for all major winter quarters also being restricted to bordering waterways.

SUMMARY

This paper summarizes the movement pattern of *M. lucifugus* from winter to summer in north-central Illinois. The recoveries show a di-

rect WSW to SSW pattern of dispersal, closely correlated with the Illinois River.

Statistical analysis (Table 2) indicates the WSW, SSW, and entire sample bearings are highly significant at the .01 level. Three individuals recovered from the east also fall within the 90° bearing, which also is closely correlated with the rivers course from the east.

It was previously felt that no movement took place between Illinois populations of *M. sodalis* and the Ozark area of Missouri. A recent recovery from Missouri shows a greater dispersal pattern than was previously hypothesized.

The greatest distance traveled by *M. lucifugus* was 105 airline miles, with an average of 25.6 miles. The Blackball Mine population is probably restricted to within a 150 mile radius. No apparent movement takes place between this mine population and either the extreme southern Illinois or northwestern Illinois populations.

Acknowledgments

I wish to thank Dr. William E. Southern and Dr. Jerrald H. Zar, Department of Biology, Northern Illinois University for constructive criticisms, and use of the computer program. Dr. Wayne H. Davis, Department of Biology, University of Kentucky for supplying data on several recoveries; also Mr. Steven Richmond for drawing the map.

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DEVELOPMENT OF LATERAL CERVICAL FAT ORGANS IN THE CHICK WITH EMPHASIS ON RELATIONSHIPS TO THE ADJACENT MUSCULUS COMPLEXUS

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ABSTRACT.—Structures immediately lateral to the Musculus complexus (hatching muscle) of chick embryos and early posthatching stages have been studied histologically and quantitatively. They proved to be fat organs rather than lymph glands as previously designated by some investigators. Possible reasons for quite parallel changes in mean fixed wet weights of the M. complexus and adjacent fat organs and diameters of vacuoles of the largest univacuolar fat cells are discussed.

In 1954 Liebelt and Eastlick described macroscopically the location, time of appearance and relative size and shape of 16 subcutaneous fat organs (fat bodies) in chick embryos. One of the largest and most distinct has an elongated triangular shape and is located in the dorsolateral cervical region (the lateral cervical fat organ). Clara (1929) had previously examined the histogenesis of some subcutaneous fat depots in a variety of birds and had recorded some observations on developing fat depots in the neck region of chick embryos, presumably on developing lateral cervical fat organs.

Other investigators interested in the peculiar developmental history of the avian hatching muscle (Musculus complexus) and its possible role in pipping and hatching had seen these prominent structures bordering the M. complexus of chick embryos (Fisher, 1958; Brandstetter, 1960; Smail, 1964, 1965; Brooks and Ungar, 1967) and had designated them as lymph glands; see illustrations in Fisher and Smail. Developmental changes in their size were reported to parallel closely changes in mass or size of the M. complexus of the chick (Fisher, 1958) and certain other birds (H. Fisher, 1962, 1966; J. Fisher, 1962), although they were absent in developing North American grebes (Fisher, 1961). Changes in size were deduced either from gross observations or from measurements of lengths and widths and sometimes from crude estimations of areas based on these measurements.

It is the purpose of this investigation on chick embryos and early posthatching stages to (1) describe the histogenesis of the structures bordering the M. complexus and to demonstrate that, at least in chicks, they are fat organs and not lymph glands and (2) ascertain to what extent weight changes and changes in diameters of individual fat cells of the lateral cervical fat organs parallel weight changes in the M. complexus.

Materials and Methods

Fertile White Leghorn eggs were used exclusively; they were incubated at 37.5°C in a forced draft incubator. All specimens were killed by decapitation at the base of the neck. Only the head and neck were preserved in Bouin's fixative and subsequently decolorized in 70% ethanol and lithium carbonate. Specimens were preserved daily between 7 days of incubation and 6 days posthatching for histological study. Selected regions (the entire neck and part of the head of younger specimens, only fat organs plus a portion of the adjacent M. complexus in chicks incubated more than 16 days) were sectioned serially in paraffin at 20 μ, both transversely and sagittally, and stained with Heidenhain's iron hematoxylin and eosin Y.

To provide material for weight determinations specimens were preserved at 13, 15 and 16 days of incubation and daily from 18 days of incubation through 3 days posthatching (Table 1). Hatchlings were given free access to water, but most were not fed. Six chicks were fed chick starter for 2 days, 18 for 3 days. Preserved fat organs and paired M. complexus muscles were then carefully isolated. The jugular vein and vagus nerve were carefully removed from these isolated organs and the latter were then blotted for 5 seconds and weighed. Mean fixed wet weights and standard errors of the means were calculated. The t-test was used to determine whether weight changes between different days were statistically significant. Most differences were highly significant ($P \leqq 0.01$), but some were only significant ($P \leqq 0.05 > 0.01$).

Observations

Gross relationships. Although the origins and insertions of the M. complexus have been repeatedly described (Beddard, 1898; Kaupp, 1918; Fisher, 1958; George and Berger, 1966; Brooks and Ungar, 1967; Bock and Hikida, 1968), the gross relationships of the muscle to the head of the chick have been illustrated only by the diagrams of Fisher (1958) and Bock and Hikida (1968, 1969) and by the photographs of Brandstetter (1960) and Smail (1964, 1965). The location and appearance of the M. complexus in a chick preserved shortly after hatching are evident in Figure 1. The muscle forms a prominent bulge at the back of the head and upper part of the neck.

The complete extent of the right lateral cervical fat organ is evident in Figure 1. It is roughly triangular in shape with the base of the triangle directed anteriorly. Its general shape and size relative to the rest of the head and neck correspond exactly with the schematic representations of the lateral cervical fat organs published by Liebelt and Eastlick (1954) to represent relationships in 12-, 14- and 16-day chick embryos.

The gross relationship of the lateral cervical fat organ to the M. complexus is also clearly illustrated in transverse section in Figure 2. The former not only lies dorsolateral to the M. complexus, but obviously extends far ventrad towards the esophagus. The lateral cervical fat organ is obviously only loosely attached to adjacent structures. Therefore it can be removed cleanly for weighing, but only in preserved

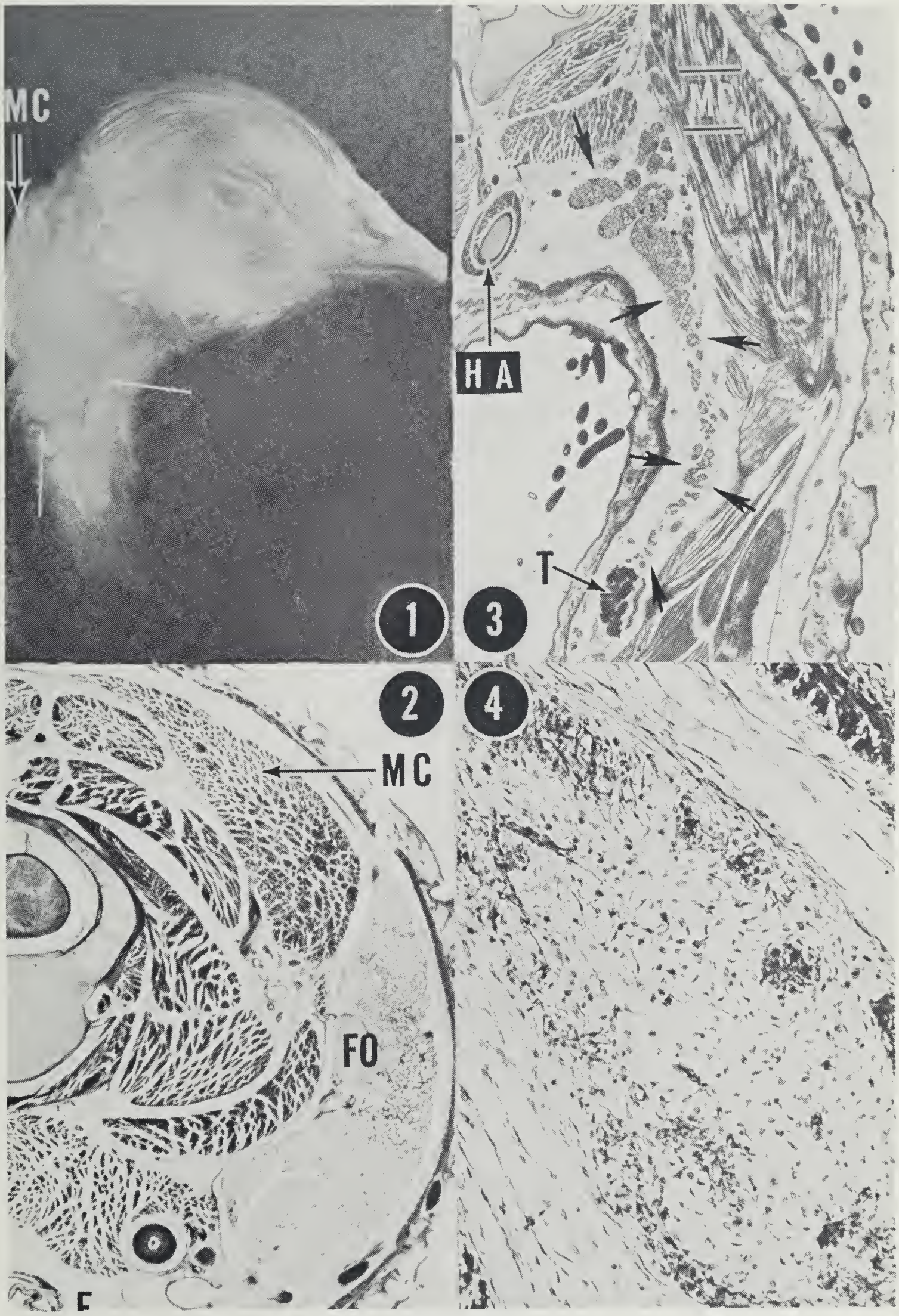

PLATE 1
(See p. 427)

specimens. In specimens used for this investigation the esophagus was frequently displaced to the right. Under these circumstances the lateral cervical fat organ was much smaller on the right side than on the left.

The lateral cervical fat organ is also roughly triangular in shape in parasagittal sections (Fig. 3). The broad anterior end lies between the M. complexus dorsally and the hyoid arch ventrally; the narrow posterior end lies in contact with the anterior lobe of the thymus. The latter is the only lymphoid organ in the neck; it obviously lies far posterior to the M. complexus. According to Hamilton (1952) the chick does not possess definite lymph nodes such as are found in mammals, although Clara (1929) refers to "Halslymphknotens."

Histogenesis. Rudiments of lateral cervical fat organs cannot be identified in specimens incubated 7½-9 days. Ten-day specimens were not examined histologically in the present investigation. By 11 days (stage 37) rudiments of these particular fat organs can be identified. A transverse section showing most of the dorsoventral extent of such a rudiment is illustrated by Figure 4. It is tear-shaped, very narrow and somewhat pointed dorsally and broad and rounded ventrally. Its connective tissue component is considerably more dense and contains many more fibers (processes?) than the adjacent loose connective tissue. The darker masses within the boundaries of the rudiment consist of capillaries or capillary networks plus adjacent adventitial cells (prospective fat cells) which form a single or double layer outside the endothelium of capillaries. Nuclei of these perivascular mesenchymal cells are distinctly different from those of fibrocytes. They are spherical or nearly so, in contrast to the oval shape of fibrocyte nuclei. Nuclei of young prospective fat cells are also generally smaller and stain more intensely than those of fibrocytes.

The larger clusters of prospective fat cells are usually found around capillary networks. Such clusters are highly variable in size and shape. Sometimes a capillary interconnects two otherwise independent clusters. Some of the prospective fat cells are undergoing mitosis. Erythrocytes occur both within capillaries and outside the latter. At 11 days fat droplets are not present; at least they cannot be detected at a magnification of 400X.

By 12 days (stage 38) boundaries of lateral cervical fat organs are very distinct in parasagittal sections (Fig. 3). Clusters of young fat cells in close relation to capillaries form more or less independent lobules separated by fibrocytes. A portion of the lateral cervical fat organ at stage 38 is illustrated at higher magnification in Figure 5. The darkest portions of this photomicrograph consist of capillaries containing erythrocytes with darkly stained nuclei. The very light portions are vacuoles from which fat was extracted by histological procedures. The largest vacuoles may be the single vacuoles of univacuolar fat cells. These are approximately 15.5 μ in diameter. Most of the vacuoles are smaller and grade down to those barely visible at a magnification of 400X. These smaller

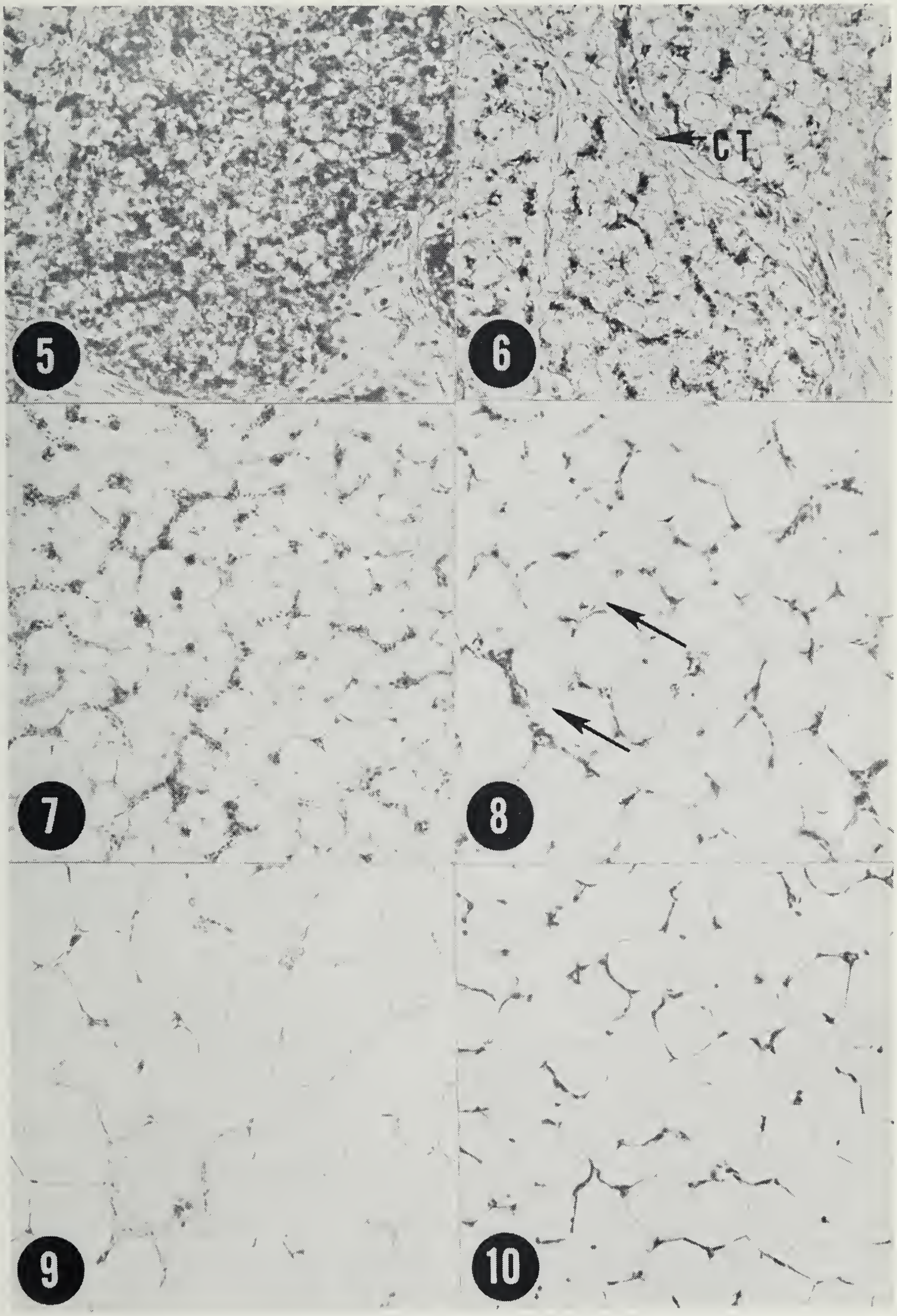

PLATE II
(See p. 427)

vacuoles are presumably located in plurivacuolar fat cells, although the outlines of individual cells cannot be identified with certainty in the thick sections used in the present investigation. Regardless of their size vacuoles are approximately circular in outline. Mitotic figures are present in some of the cells containing small vacuoles. Therefore the presence of fat droplets is compatible with mitotic division. Very few fibrocytes are present within fat lobules, but they separate lobules from one another.

By 13 days (stage 39) increasing numbers of fat cells are of the univacuolar type (Fig. 6). Lobules are now closely adjacent to one another, separated only by thin septa formed by fibrocytes. Capillaries filled with erythrocytes containing darkly stained nuclei are very evident, but are more widely separated than at 12 days (compare with Fig. 5). Diameters of the largest vacuoles, presumably the single vacuoles of univacuolar fat cells, now measure approximately 25 μ. Many plurivacuolar fat cells are still present; their vacuoles vary markedly in size. Mitotic figures are much less common than at 12 days.

The appearance of 14-day lateral cervical fat organs is not illustrated since Clara (1929) published a very accurate drawing of this stage in his Figure 10. Univacuolar cells continue to increase in diameter and become closely applied to one another. Plurivacuolar cells assume very irregular shapes and occupy whatever space is available between enlarging univacuolar cells and capillaries.

By 15 days (stage 41) the cross-sectional area of the lateral cervical fat organ is very large compared with other structures in the neck region (Fig. 2). Higher magnification (Fig. 7) shows that most fat cells are now of the univacuolar type. Diameters of the largest vacuoles usually have increased to approximately 34.5 μ, but a few have increased to 44 μ. Capillaries become increasingly compressed by enlarging fat cells. Some plurivacuolar cells are still present; their contained vacuoles are still of variable size. However, the number of plurivacuolar cells has clearly decreased as increasing numbers of them transform into univacuolar cells. Mitotic figures are very rare and are found only in the smallest fat cells.

With continued incubation diameters of the largest univacuolar fat cells continue to increase to approximately 72 μ at 16 days (stage 42, Fig. 8) and to 81 to 91.5 μ at 19-20 days (stage 45, Fig. 9). Plurivacuolar cells are still evident at 16 days (arrows, Fig. 8) but they, as well as capillaries, are progressively less evident as hatching time approaches. At 16 days outlines of individual univacuolar fat cells are still approximately circular (Fig. 8), but by 19-20 days (Fig. 9) the shapes of these cells become very much modified as the very large cells compress one another.

In posthatching stages (Figs. 10-12) the appearance of univacuolar fat cells does not change appreciably, but diameters of the largest ones decrease appreciably shortly after hatching: 78 μ at 1 day posthatching (Fig. 10); 59.5 μ at 3 days posthatching (Fig. 11); 47 μ at 6 days posthatching (Fig. 12). During

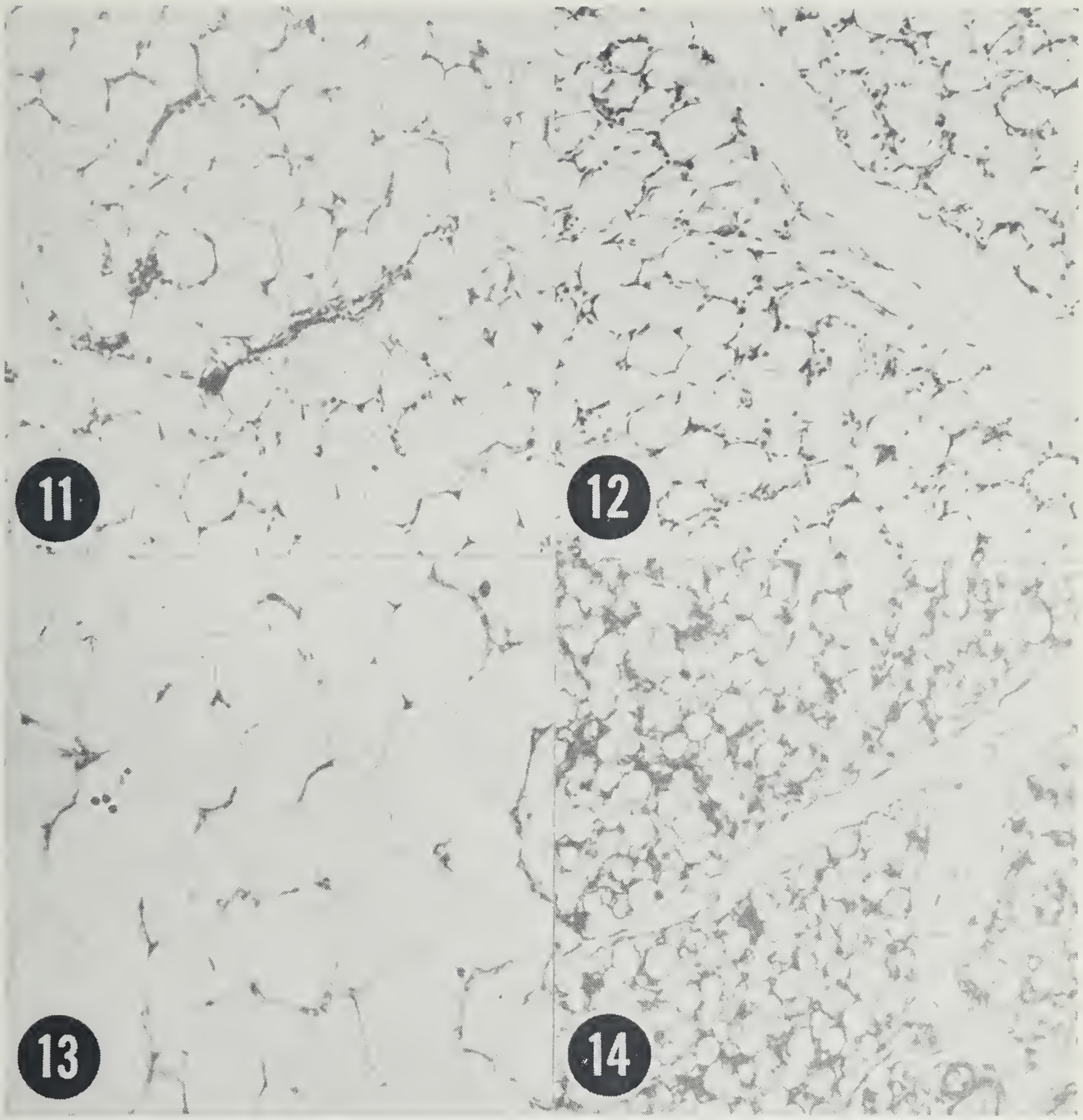

PLATE III
(See p. 427)

posthatching stages lobules within lateral cervical fat organs become increasingly separated from one another (Fig. 12) and capillaries become increasingly evident.

It is not known whether all fat organs of chickens undergo the same developmental sequence involving first an increase and then a decrease in the size of individual fat cells. But if they do, corresponding changes apparently do not occur at the same time in all fat organs. At 21 days of incubation the histology of the lateral *abdominal* fat organ (Fig. 13) is essentially the same as that of the lateral cervical fat organ of 19- to 20-day chick embryos (Fig. 9). By contrast, the histology of the lateral *thoracic* fat organ at 21 days (Fig. 14) is entirely different. The latter has either failed to develop to the same extent as the other 2 fat organs or, more likely (see

below), has secondarily lost much of its fat content.

Quantitative changes. Mean fixed wet weights of paired M. complexus and paired lateral cervical fat organs are recorded in Table 1 and are plotted in Figure 15. For comparison the unpublished data of Watterson and Veneziano on mean fresh weights of the M. complexus are also plotted in Figure 15. At 2 and 3 days posthatching (23 and 24 days from onset of incubation) data were obtained and plotted for both fed and unfed chicks.

Mean fresh weights of the M. complexus increase rapidly to a peak at 20 days, the day of pipping, then decrease rapidly. Mean fixed wet weights behave somewhat differently. They increase slightly from 13 to 16 days (although the apparent increase between 15 and 16 days is not statistically significant), then increase rapidly to an apparent maximum at 21 days (although differences between 18- and 19-day and between 20- and 21-day values are not statistically significant) and then decrease progressively and rapidly. Values at 21 to 23 days are quite similar to fresh weight values, but fresh weight values are consistently larger than fixed weight values at earlier stages, especially at 19 and 20 days when the water content of the M. complexus is normally very high. Fixed weight values in posthatching stages are the same in fed and unfed chicks (Table 1).

Mean fixed wet weights of lateral cervical fat organs are slightly larger at 13 and 16 days than mean fixed wet weights of the M. complexus. Values increase slowly during this interval (but the apparent

TABLE 1.—Mean fixed wet weights (mgs) of paired M. complexus and paired lateral cervical fat organs

Age (days of incubation)	Number of Specimens	Musculus complexus (mgs)	Standard Error	Lateral Cervical Fat Organs (mgs)	Standard Error
13	5	29.19	±2.12	35.52	±2.87
15	5	39.72	±3.93	54.42	±6.49
16	5	45.28	±3.19	64.98	±5.29
18	5	172.56	±20.35	116.80	±12.08
19	6	177.79	±14.04	131.11	±15.18
20	21	315.00	±22.49	211.58	±9.07
21 (just hatched)	21	346.20	±19.68	202.91	±8.19
22 (1 day post-hatching)	21	245.91	±11.13	196.41	±7.93
23 (2 days post-hatching; unfed)	21	192.34	±6.40	157.97	±6.45
23 (2 days post-hatching; fed)	6	187.86	±17.99	187.83	±16.99
24 (3 days post-hatching; unfed)	24	149.29	±5.97	117.24	±8.70
24 (3 days post-hatching; fed)	18	149.64	±4.75	131.52	±6.57

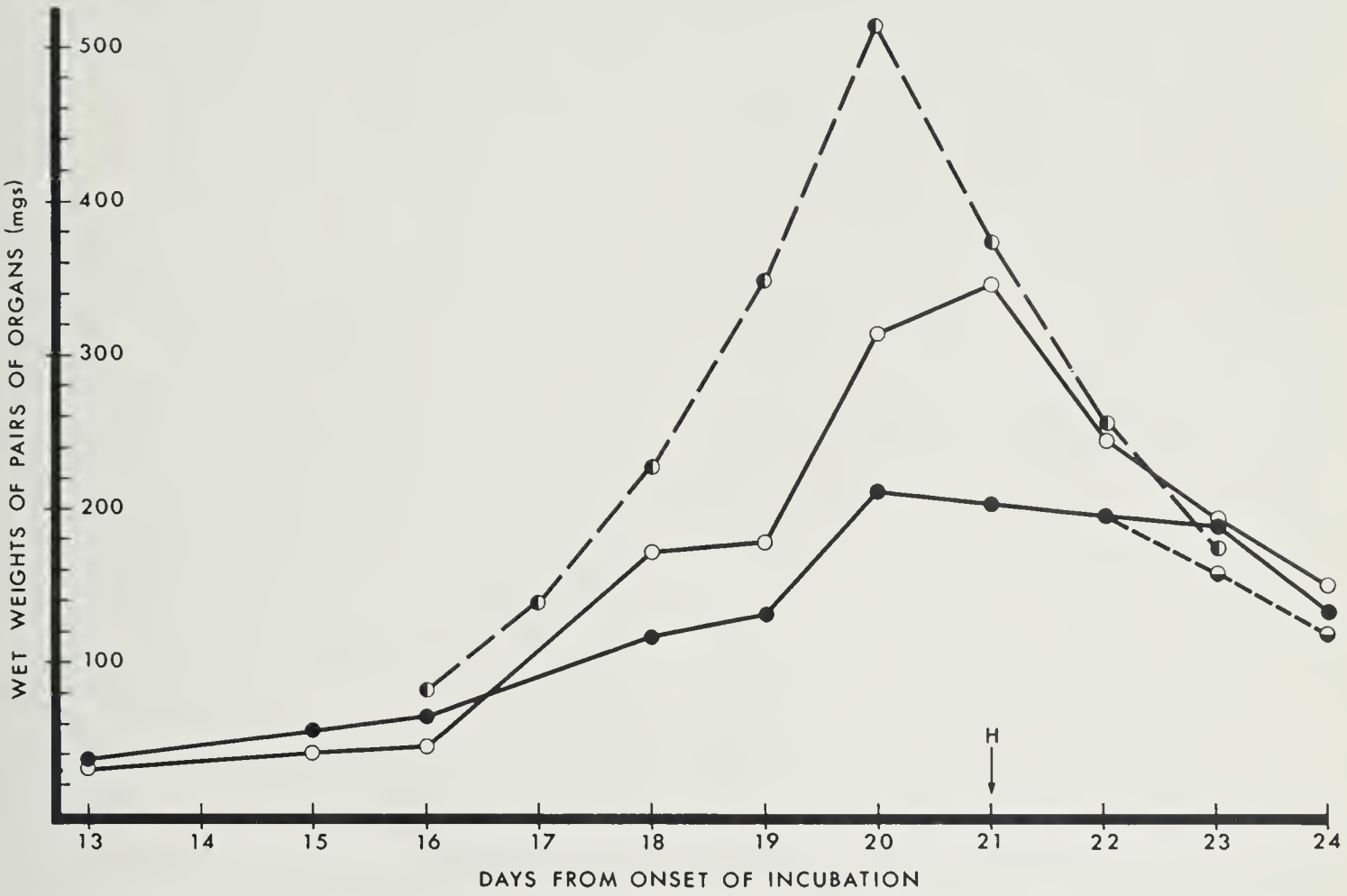

FIGURE 15. Comparison of changes in mean fresh weights of the paired M. complexus (shaded vertical half circles, unpublished data of Watterson and Veneziano from Smail, 1965) and mean fixed wet weights of the paired M. complexus (open circles) with mean fixed wet weights of pairs of lateral cervical fat organs (closed circles). At 23 and 24 days values for fat organs are plotted separately for fed (closed circles) and unfed (shaded horizontal half circles) chicks.

increase from 15 to 16 days is not statistically significant). Thereafter they increase less rapidly than those of the M. complexus to 20 days. The apparent difference between 18- and 19-day values is not statistically significant. Values remain unchanged at 21 to 23 days in fed chicks, then decrease significantly. In unfed chicks values decrease significantly at both 23 and 24 days. Mean fixed wet weights of lateral cervical fat organs in fed chicks are approximately the same as mean fixed wet weights of the M. complexus at 23 and possibly at 24 days; they are somewhat smaller than the latter in unfed chicks.

DISCUSSION

Many investigations have demonstrated that a large amount of fluid accumulates in the M. complexus of various birds just prior to pipping (Keibel, 1912; Pohlman, 1919; H. Fisher, 1958, 1961, 1962, 1966; Brandstetter, 1960; George and Iype, 1963; Smail, 1964, 1965; Watterson *et al.*, 1964; Brooks and Ungar, 1967; Bock and Hikida, 1968, 1969; Klicka *et al.*, 1969; Ramachandran *et al.*, 1969). Consequently, at the time of pipping, the muscle is very turgid and muscle bundles, as well as individual muscle fibers within bundles, are widely separated

from one another (Fisher, 1958; Brandstetter, 1960; Bock and Hikida, 1968, 1969).

According to H. Fisher (1962, 1966) and J. Fisher (1962) the fluid content of the M. complexus is somehow transferred to it from structures immediately bordering the muscle which they designated as lymph glands, lymph nodes or lymph areas. However, grebes lack such structures; nevertheless the M. complexus is selectively infiltrated with fluid just prior to pipping (Fisher, 1961). Moreover, Smail (1965) pointed out that a flow of lymph into a muscle would be surprising and Bock and Hikida (1969) noted that such a hypothetical flow of fluid would encounter considerable resistance due to the turgidity of the M. complexus. The latter investigators completely rejected the hypothesis of a flow of lymph into the hatching muscle from outside sources and reiterated their earlier suggestion (Bock and Hikida, 1968) that the lymph arises within the muscle due to osmotic pressure generated there, a possibility suggested earlier by Smail (1965). George and Iype (1963) suggested that the increased water content of the M. complexus might represent metabolic water resulting from vigorous muscular activity.

The present investigation demonstrates that the structures adjacent to the M. complexus of developing chicks are not lymph glands. Instead, on the basis of their location, size, shape and histogenesis they appear to be the lateral cervical fat organs of Liebelt and Eastlick (1954). Their histogenesis is the same as that of various normal subcutaneous fat depots described by Clara (1929) in a variety of birds. Moreover, the histogenetic changes in these structures are the same as those which occur in fat organs which develop in chick limb buds transplanted to the coelom of host embryos (Eastlick and Wortham, 1947; Miller and Eastlick, 1952). Preliminary observations indicate that the structures bordering the developing M. complexus of White Pekin ducks are also fat organs. Such findings should terminate debates about the possible transfer of fluid to the M. complexus from structures immediately bordering these muscles, at least in chick and duck embryos, and should focus attention on developmental changes within the M. complexus itself which might be responsible for the selective accumulation of fluid by this muscle.

According to H. Fisher (1962, 1966) the structures bordering the M. complexus of various birds increase and decrease in size more or less parallel to changes in size of the muscle itself. The present investigation demonstrates that mean fixed wet weights of the lateral cervical fat organs bordering the M. complexus of chick embryos tend to increase and decrease in somewhat similar fashion except at 21 days of incubation (Fig. 15), especially in unfed chicks. Similarly, the present investigation demonstrates that diameters of vacuoles in the largest univacuolar fat cells of the lateral cervical fat organs of the chick (and thus diameters of the cells themselves) increase to maximal values at 19-20 days of incubation and decrease rapidly in posthatching stages. Such findings suggest that

the fat content of the lateral cervical fat organs is broken down in part at the time of pipping and hatching, possibly to provide fatty acids as energy sources for the muscular activity involved in these processes.

In this connection it is interesting that by 19 or 20 days of incubation lipoprotein lipase, one of the enzymes capable of splitting fatty acid from parent triglycerides, exhibits a surge of activity in lateral thoracic fat organs of chick embryos (Feldman *et al.*, 1962b). Should such a surge of activity of this enzyme likewise occur at this time in other subcutaneous fat organs of chick embryos, including the lateral cervical fat organs bounding the M. complexus, the decreased diameters of the largest fat cells and the reduction in mean fixed wet weights of the lateral cervical fat organs of posthatching stages could be accounted for without assuming that these changes were related only to developmental changes undergone by the M. complexus. Even so, the latter muscle might profit more from these changes in fat organs in general than other muscles. Hsiao and Ungar (1969) demonstrated a 40% decrease in total lipid content and a 41% decrease in triglyceride content in the hatching muscle between 17 and 21 days of incubation, compared with decreases of only 25% and 11%, respectively, in shank (gastrocnemius) muscles. This suggests, contrary to George and Iype (1963) that the M. complexus may derive part of its energy from fat as well as from its glycogen content. The latter is depleted or sharply decreased by 21 days of incubation (see also Klicka *et al.*, 1969, and Ramachandran *et al.*, 1969) although the acid mucopolysaccharide content increases markedly at 20 days of incubation (Klicka *et al.*, 1969). More complete utilization of its own total lipid and triglyceride stores might make the M. complexus more dependent on fatty acids released into the blood from fat organs than other skeletal muscles, at least during pipping and hatching (see Feldman *et al.*, 1962a).

Summary

The gross relationships and histogenesis of the structures immediately lateral to the Musculus complexus of chick embryos have been described. These structures are typical fat organs and not lymph glands, as they have been designated by some investigators. Their mean fixed wet weights increase and decrease somewhat parallel with changes in mean fixed wet weights of the M. complexus, as do the diameters of the fat vacuoles of the largest univacuolar fat cells. These findings suggest that the fat content of subcutaneous fat organs is broken down in part at the time of pipping and hatching, possibly to provide fatty acids as energy sources for the muscular activity involved in these processes. It is suggested that fatty acids released into the blood from fat organs might be more important energy sources for the M. complexus than for other skeletal muscles at this time.

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Manuscript received August 31, 1970.

LEGENDS

PLATE I

FIGURE 1. Boundaries of the right lateral cervical fat organ in a newly hatched (21-day) chick are indicated by white arrows; MC = M. complexus. X2

FIGURE 2. Transverse section through the neck of a 15-day (stage 41) chick embryo at the level of the second vertebra. FO = lateral cervical fat organ; E = esophagus. X15

FIGURE 3. Parasagittal section through the upper neck and posterior head of a 12-day (stage 38) chick embryo. Arrows indicate boundaries of the lateral cervical fat organ. HA = hyoid arch; T = thymus gland. X16.

FIGURE 4. Transverse section through the rudiment of one lateral cervical fat organ before fat deposition begins (11 days, stage 37). X198.

PLATE II

FIGURE 5. Part of the lateral cervical fat organ at 12 days (stage 38). Magnification of Figures 5-14 x160.

FIGURE 6. Part of the lateral cervical fat organ at 13 days (stage 39). CT = connective tissue septum.

FIGURE 7. Part of the lateral cervical fat organ at 15 days (stage 41).

FIGURE 8. Part of the lateral cervical fat organ at 16 days (stage 42). Arrows indicate irregularly shaped plurivacuolar fat cells.

FIGURE 9. Part of the lateral cervical fat organ at 19-20 days (stage 45).

FIGURE 10. Part of the lateral cervical fat organ 1 day posthatching.

PLATE III

FIGURE 11. Part of the lateral cervical fat organ 3 days posthatching (unfed chick).

FIGURE 12. Part of the lateral cervical fat organ 6 days posthatching (fed).

FIGURE 13. Part of the lateral *abdominal* fat organ in a newly hatched (21-day) chick.

FIGURE 14. Part of the lateral *thoracic* fat organ in a newly hatched (21-day) chick.

NEW DISTRIBUTION RECORDS FOR *DULICHIUM ARUNDINACEUM* (L.) BRITT. IN SOUTHERN ILLINOIS

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ABSTRACT. — Field work in the Pine Hills area of Union County and the Oakwood Bottoms Green-Tree Reservoir area of Jackson County has revealed for the first time that the three-way sedge (*Dulichium arundinaceum*) grows in these two locations.

While conducting a variety of biological investigations during the summer and fall months of 1969 in Union and Jackson Counties, a new species of vascular plant was discovered growing in these two counties. The three-way sedge (*Dulichium arundinaceum* (L.) Britt.) was found thriving in a single location in each county.

In Union County, approximately two dozen stems were observed along the south edge of LaRue Spring in the Pine Hills section of the county. LaRue Spring, dominated by water cress (*Nasturtium officinale*) and sowbugs (*Lirceus fontinalis*), maintains a year-around water temperature of about 54 F. In all probability the three-way sedge stems all originate from a single rootstock.

In Jackson County, approximately 12 stems were encountered along the south side of the John's Spur Forest Service road, about one-quarter mile west of the Big Muddy River Levee, adjacent to the managed portion of the Oakwood Bottoms Green-Tree Reservoir. These plants grow in a savanna-like area in fairly wet soil.

Mohlenbrock and Voigt (1959:103-104) stated that the three-way sedge, "is found in low swampy woods of Johnson and Massac Counties." These authors also stated that, "This species should be sought in Oakwood Bottoms of Jackson County near Grand Tower." Although the two locations where the sedge plants were found differ somewhat from those described for nearby counties, they had been expected to exist in at least one portion of Jackson County over a decade ago. A rather lengthy period of time elapsed before actual discovery was made, however.

Specimens have been deposited in the herbarium at Southern Illinois University in Carbondale. The plants occurring at these two isolated sites should be preserved because of their rareness in southern Illinois.

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MOIRE PATTERNS FOR THE ADVANCED UNDERGRADUATE LABORATORY

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In trying to find open ended advanced optics experiments, the determination of index of refraction gradients by use of Moire patterns is often overlooked. While the literature (Oster, Wasserman and Zwerling, 1964) contains many articles there is invariably a lack of information on experimental procedure or detail. We have found that the following arrangement yields good results.

To make quantitative measurements it is necessary to have a sample cell, 15.0cm x 15.0cm x 1.0cm will do, with the resulting interface between the two diffusing liquids horizontal. The Moire fringes should be vertical and to accomplish this, usually, two plates of very nearly the same rulings per centimeters are used, one on each side (Van Oss, 1964). Since these are difficult to make or expensive, we used two standard 4″ Ronchi rulings of the same number of lines. Light from a collimated monochromatic source was sent through the first ruling, then through the sample cell and finally by use of a lens was projected on the second ruling. This magnification allowed for a variable relative difference in the lines per centimeter. The entrance ruling is aligned so its lines are horizontal (i.e.: parallel to the liquid interface) while the second ruling is tilted at some angle to the first. This angle is adjusted so the fringes are vertical (i.e.: perpendicular to the liquid interface). In this configuration all displacements in the pattern due to diffusion at the interface are perpendicular to the pattern and yield, generally, a gaussian shape. If the two liquids have indices of refraction N_0, N_1 and their difference is small we have

$$N(x) = N_0 \pm K\int_0^x y\,dx$$

where x is the distance measure along the base line or original fringe, and y the displacement from the base line. The constant K is complex and depends on the angle of rotation and number of lines on the Ronchi rulings, the cell wall thickness, the focal length of the lens and the wavelength. To find this constant a calibration was done with the following standard solution, which was found to be best after many combinations were tried; pure butanol and a saturated mixture of butanol and water. Since water is only slightly soluable in butanol the gradient is not too sharp. The indices of refraction of the two solutions were measured with a refractometer and then a photograph of the fringes allowed the determination of K, and of the plus and minus sign. The sign varies depending on whether the upper or lower liquid has the larger index of refraction, which in turn produces a pattern shift to the left or right. This value was found to yield good results when water and various glycerol-water solutions were allowed to diffuse. For example, a 10% glycerol-water solution yielded n = 1.3477 compared to a refractometer reading of 1.3473. (Figure 1)

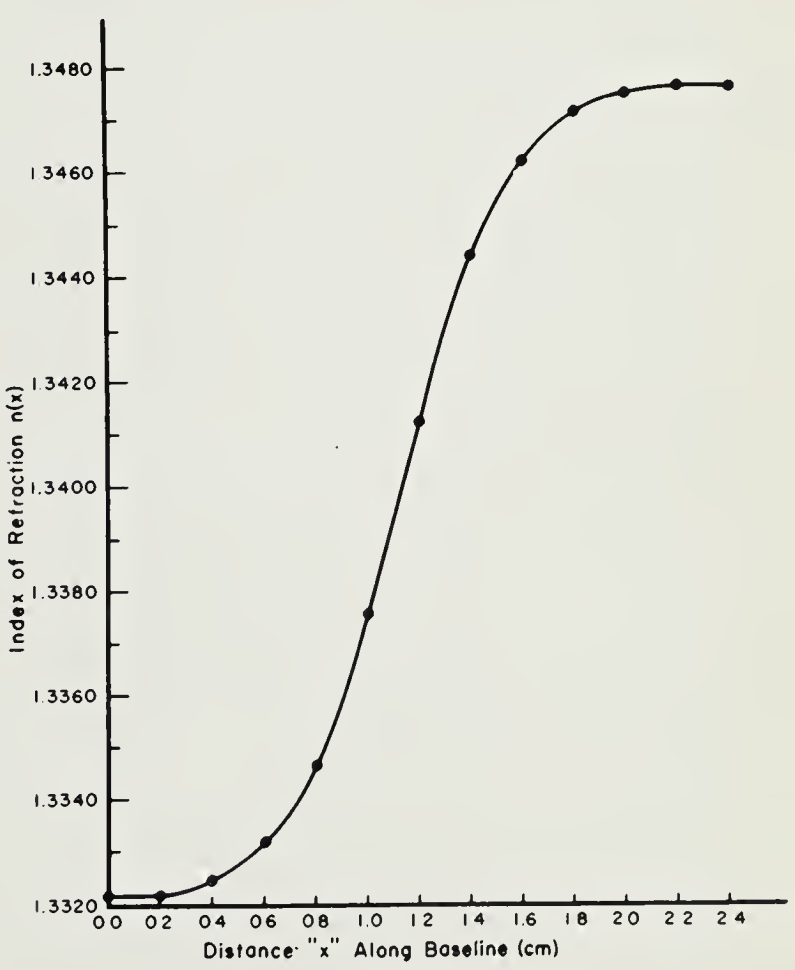

FIGURE 1. Refractive index across the boundary of a mixture of 10% glycerol-water and pure water 75 minutes from start of diffusion.

The experimental set-up is therefore: 1) a strong monochromatic source (Osram Sodium Lamp), 2) collimator, 3) first Ronchi ruling, 4) sample cell, 5) lens of long focal length, 6) second Ronchi ruling, and 7) a standard spectroscopic plate. Exposure times were less than ½ second. The distance between the two Ronchi rulings should be four times the focal length of the lens.

Temperature gradients in flames are easily measurable as are "temperature waves" propagated through carbon tetrachloride as the surface is cooled rapidly by forced evaporation.

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Manuscript received December 18, 1969.

FORMER PRESIDENT DIES

Professor Harold R. Wanless, a former president of the Illinois State Academy of Science, died June 3, 1970. Born December 5, 1898, Professor Wanless graduated from Waller High School in Chicago and took his BSc, MA and PhD degrees at Princeton. He became a member of the Geology Faculty of the University of Illinois retiring in 1967, also holding an administrative position from 1946 to 1947.

The Professor's interests were mainly in stratiography and sedimentation of carboniferous rocks of North America and Australia, regional lithofacies studies, cyclical sedimentation, interpretation of aerial photography, and tertiary non-marine sediments. In following these interests Dr. Wanless became a life member of the Illinois Academy of Science, a member of the State Geological Survey of Illinois and of the United States Geological Survey. He was also a senior Fulbright research fellow at the University of Sydney (Australia) during the academic year 1958-1959 and a member of the carboniferous subcommittee of the International Geological Congress in 1960. *Dr. Boris Musulin, Chemistry, Southern Illinois University, Carbondale 62901.*

Manuscript received June 8, 1970.

RAYMOND J. DOBBS
1883-1970

ROBERT A. EVERS
State Natural History Survey
Urbana 61801

Raymond J. Dobbs, a member of the Illinois State Academy of Science since 1940, died in Miami, Florida, on January 31, 1970, at the age of 87 years and 21 days.

Mr. Dobbs was born in Geneseo, Henry County, Illinois, on January 10, 1883, the only child of Mr. and Mrs. Joseph Dobbs, pioneer residents of that community. His boyhood was spent in Geneseo and he graduated from Geneseo High School. The next year he taught school, not an uncommon activity for high school graduates in those years, and then entered Shurtleff College at Alton, Illinois. In 1907, Mr. Dobbs graduated with a degree of Bachelor of Science and with highest honors for scholarship. Later he entered the Northern Illinois College of Ophthalmology and Otology in Chicago where he studied optometry. After graduation, he practiced optometry in Geneseo for a number of years.

His great interest in the out-of-doors persisted from youth and upon retirement from his practice in Geneseo, Mr. Dobbs went to California where he served as a naturalist and guide at a large resort near Pasadena. In his eight years at this resort he conducted nearly 8,000 people over more than 5,000 miles of mountain trails. In addition, he gave many lectures on the natural history of the region. In 1926, he entered the Yosemite School of Field Natural History.

He was one of only 20 students admitted to this school from the United States. After graduation, he was again honored, being one of two selected from his class to act as United States Government Naturalist in Yosemite. For some time he conducted nature study trips and gave numerous lectures for park visitors.

Mr. Dobbs returned to Geneseo in 1930, to be with his parents during their declining years. In 1934, he began a botanical survey of Henry County, Illinois, "as a scientific contribution, . . ., and under no official auspices." He maintained a schedule of two trips a week to various parts of the county during the collecting season and he did not abandon his collecting during World War II, in spite of gasoline rationing. For 22 years he botanized in Henry County (and some elsewhere), preparing specimens for herbaria and taking notes. These activities culminated in 1963 in his publication of "Flora of Henry County, Illinois" in which he included 1,294 species, varieties and forms, of which he considered 1,233 as the persistent, spontaneous flora of that county.

On May 15, 1944, Mr. Dobbs was married to Mrs. Grace Armstrong. For the next nine years this couple travelled extensively by automobile and finally realized their ambition — visiting, at least once, every state in the Union, Hawaii and Alaska excepted. They also travelled in Mexico and in some of the provinces of Canada — British Columbia, Ontario, Que-

FIGURE 1. Raymond J. Dobbs, February, 1941.

bec, New Brunswick, and Nova Scotia. In Quebec they drove around the botanically interesting Gaspé Peninsula. Although he travelled "to see the country," Mr. Dobbs also examined the flora of the countryside through which he travelled and compared the plants with those of Henry County. On May 12, 1953, Mrs. Dobbs died. Two years later the widower left Geneseo, moved to Miami, Florida, and became a resident of that state. He resided in Miami to his death. He is survived by a number of cousins.

During the early years of his botanizing in Henry County, Mr. Dobbs became acquainted with the late Dr. Leo R. Tehon, botanist of the Illinois Natural History Survey. Dr. Tehon assisted him in those years by making identifications of grasses, sedges and asters and Mr. Dobbs placed his Henry County specimens in the herbarium of the Illinois Natural History Survey. He was also acquainted with Dr. Charles C. Deam, author of the "Flora of Indiana" and botanized with him in southern Florida in 1949. He knew the late Professor M. L. Fernald of the Gray Herbarium of Harvard University, who named a variety of wood betony in his honor. Mr. Dobbs was also honored by the late Dr. L. H. Bailey of the Bailey Hortatorium of Cornell University who named a new blackberry from Henry County *Rubus dobbsii.*

Although I was acquainted with the name R. J. Dobbs as the collector of herbarium specimens that I examined at the Survey during summers from 1938 - 1942, it was not until after World War II that I met him. In 1946, we were both on the program of the Botany Section of the Illinois State Academy of Science in the meetings at Normal. Mr. Dobbs presented a paper, "Illustrated Notes on the Flora of Henry County," published in the *Transactions.* During my first few years of work at the Survey, I had the pleasure of visiting with Mr. Dobbs on his visits to the Survey herbarium, usually made while enroute from Geneseo to Florida.

Men like Mr. Dobbs are rare individuals. Many persons have started a botanical survey of their county. Not many complete it. Mr. Dobbs did. He not only made an intensive survey but he also published his results. Although he kept no record of the miles he travelled by automobile during the 22 years of collecting, he used seven or eight automobiles in that time. Certainly he was not restricted to "automobile botanizing" for his pedometer readings showed he walked 200-300 miles during a field season. No small item in these activities was the expense involved, all of which he bore himself. I must agree with Dr. Lloyd H. Shinners who, in reviewing Dobb's *Flora,* wrote in Sida 1(4): 254, 1964, "One would like to devise a special medal to award to those who do not demand inflated N.S.F. grants, a pack of assistants, and the ballyhoo and flummery that have become a routine part of American science, but who calmly, objectively, and conscientiously devote themselves to straightforward accomplishment of straightforward scientific tasks. Its recipients would be rare birds indeed." Raymond J. Dobbs would have received such an award. He was such a man.

Manuscript received May 21, 1970.

GEORGE NEVILLE JONES
1903-1970

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George Neville Jones, professor of botany and curator of the herbarium of the University of Illinois at Champaign-Urbana, and a member of the Illinois State Academy of Science, died in Burnham City Hospital, Champaign, Thursday, June 25, 1970, at the age of 67 years. He never recovered from injuries he received in an automobile accident on Easter morning, April 14, 1968, while he and Mrs. Jones were en route to Allerton Park.

Professor Jones was born January 26, 1903, in Boston, Lincolnshire, England, a son of Alfred Loft and May Neville Cooke Jones. The family moved from England to Canada where the father worked for a seed company in Brandon, Manitoba. It is quite possible that Dr. Jones' interest in plants began at this time. From Canada the family moved to Seattle, Washington.

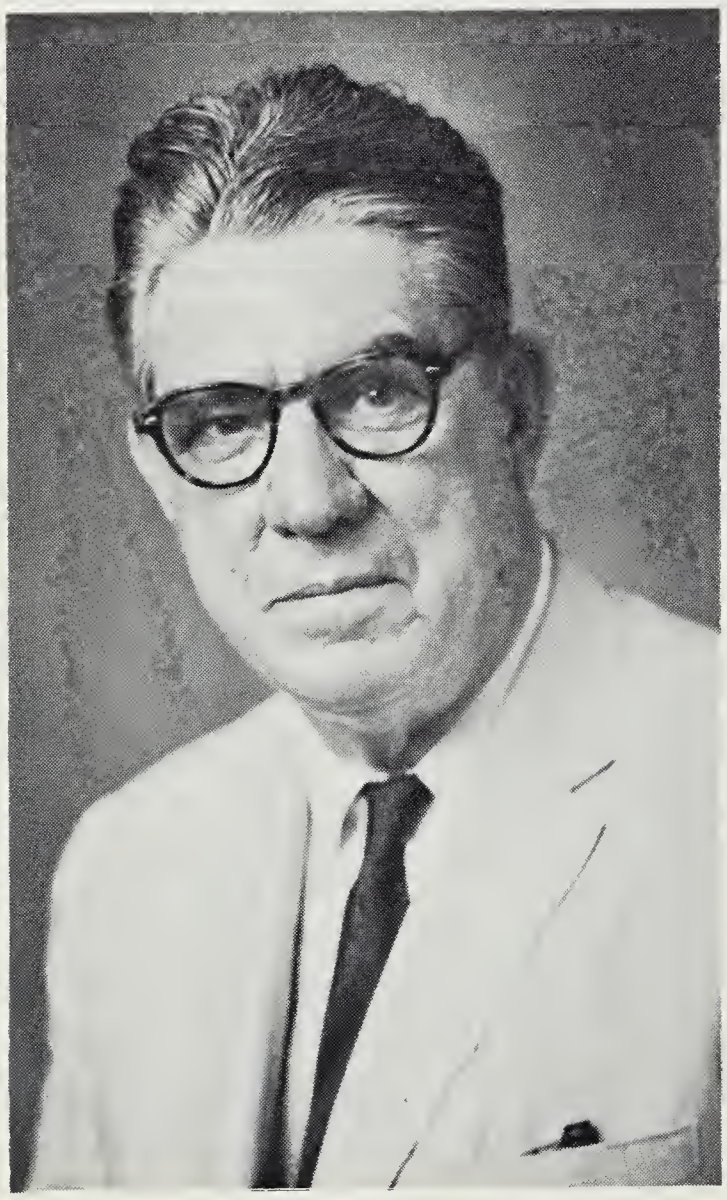

FIGURE 1. George Neville Jones 1903-1970.

In 1930, he received his Bachelor of Science degree from State College of Washington, Pullman. From the University of Washington, Seattle, he obtained his Master of Science degree in 1932 and his Doctor of Philosophy degree in 1937. His doctoral dissertation was a study of the flowering plants and ferns of Mount Rainier. The publication is still in demand as is also his earlier work on a botanical survey of the Olympic Peninsula, Washington.

In 1937, he went to Harvard University where he served as instructor in biology, tutor in the division of biology, and technical assistant in the Arnold Arboretum. While at Harvard and the Arboretum he became acquainted with Professor M. L. Fernald and Dr. Alfred Rehder.

In 1939, Dr. Jones came to the University of Illinois as instructor in botany. Not since the retirement of Dr. William Trelease did the botany department have a trained taxonomist on the staff nor was there an official curator of the herbarium. Various members of the staff were assigned to teach the class in plant taxonomy; the last on this basis was Professor Harry J. Fuller. Dr. Jones' arrival thus filled a long vacant position in the department of botany. When he came to the University, he was preparing a monograph on *Symphoricarpos,* which he soon completed. He very soon became interested in the flora of our state and began his studies which culminated, in 1945, in the publication of the first edition of the "Flora of Illinois."

Dr. Jones moved through the ranks of assistant professor and associate professor and, in 1950, became full professor in the department. He held this title in high esteem, not alone for the rights it bestowed but also for the responsibilities it carried. For example, he regularly attended the meetings of the University Senate.

When the University assumed control of Allerton Park near Monticello in 1948,

Professor Jones began a study of its flora. He spent most weekends from that time until the unfortunate accident of April 14, 1968, at Allerton Park, observing and collecting plants. These collections, containing nearly 900 species of mosses, ferns, and flowering plants, form a separate section of the Herbarium of the University of Illinois. His work in the park added much to the botanical knowledge of the area.

Professor Jones did not limit his botanizing to Allerton Park and Illinois. He collected in all but three states of the United States and in many of the provinces of Canada. He spent 15 summers collecting plants in the Rocky Mountains. In 1958, he received a grant from the National Science Foundation to travel to Mexico and study *Tilia mexicana*. While there he collected numerous specimens and became interested in the ferns of Mexico. In 1959 and 1966, he collected in Europe.

During his 30 years as curator, the herbarium more than doubled in size. He exchanged his duplicate specimens with more than 100 universities, botanical gardens, museums, and scientific institutions in North America and Europe, thus enriching the herbarium of the University. Numerous botanists visited the herbarium for study of specimens during the time he was curator.

In addition to his activities at the University of Illinois—teaching, research, advising graduate students, and committee work—he served as associate editor and reviewer for systematic botany for the American Midland Naturalist. He was a Guggenheim Fellow in 1944, a visiting lecturer at the University of Wisconsin in 1947, and at the University of Colorado in the summers of 1960 through 1965. In 1967, he received from the American Library Association the Eunice Rockwell Oberly Award for his "Annotated Bibliography of Mexican Ferns," judged the best bibliography in the field of agriculture or related sciences for that year.

Professor Jones read a great deal. In addition to the many botanical publications, he found time to read books and periodicals in other fields. One of his favorite authors was Sir Winston Churchill. For some graduate students, the stories of O. Henry took on new luster when, on an occasion of relaxation, Professor Jones would pick up a copy of short stories of that author and read aloud to those present. These lucky students never forgot such occasions.

Professor Jones was a member of the American Association for the Advancement of Science, the American Association of University Professors, the American Bryological and Lichenological Society, the American Fern Society, the American Society of Plant Taxonomists, the Botanical Society of America, the California Botanical Society, the Illinois State Academy of Science, the Indiana Academy of Science, the International Association for Plant Taxonomy, the International Society of Plant Morphologists, the New England Botanical Club, Sociedad Botánica de México, and Sigma Xi.

He is survived by his widow, Almut, and two daughters, Margaret, of Stamford, Connecticut, and Elizabeth, of Los Angeles, California, as well as five brothers and one sister.

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Manuscript received September 14, 1970.

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